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(54) **METHOD FOR INTER-ENTERPRISE ROLE-BASED AUTHORIZATION**

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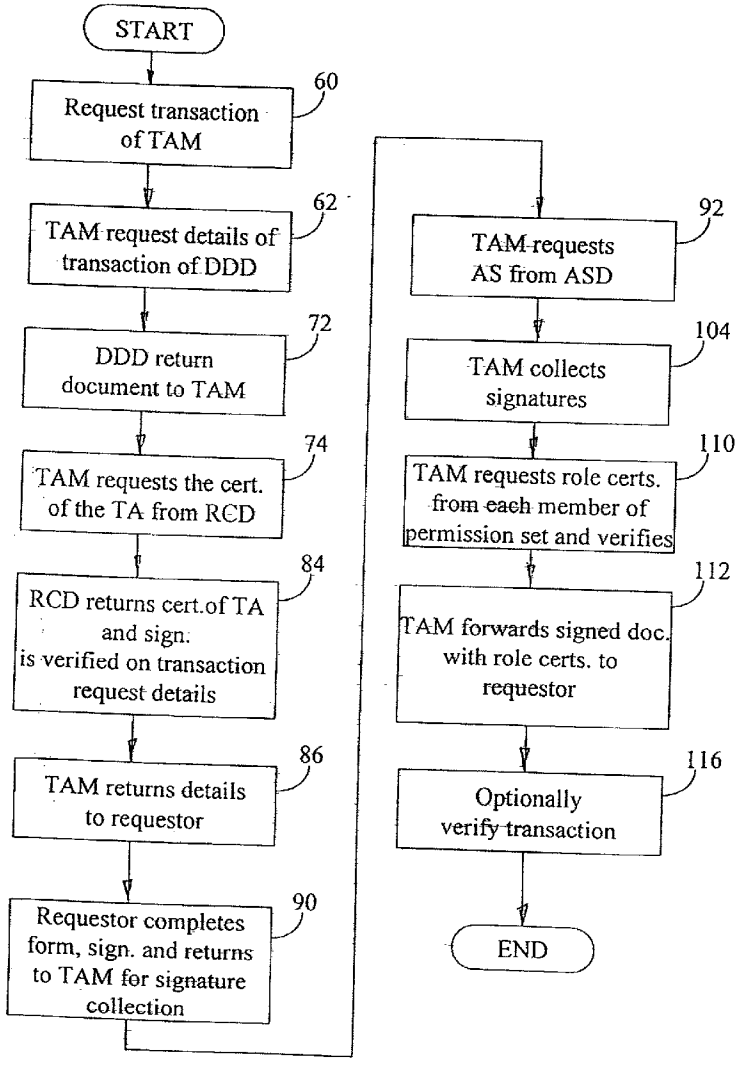
(57) **ABSTRACT**

A Transaction Authorization Method operating over a computer network comprising a plurality of interconnected computers and a plurality of resources, each computer including a processor, memory and input/output devices, each resource operatively coupled to at least one of the computers and executing at least one of the activities in the process flow, the method characterized in that it assembles an electronic authorization of a transaction in a manner which is verifiable by extracting and verifying whether role certificates of at least one type, associated with the authorization, are themselves authentic. The method eliminates the need of having to authorize each and every signature on a transaction individually by providing an authorization structure based on roles, this structure being accessible on a public network for verification that the transaction is authorized.



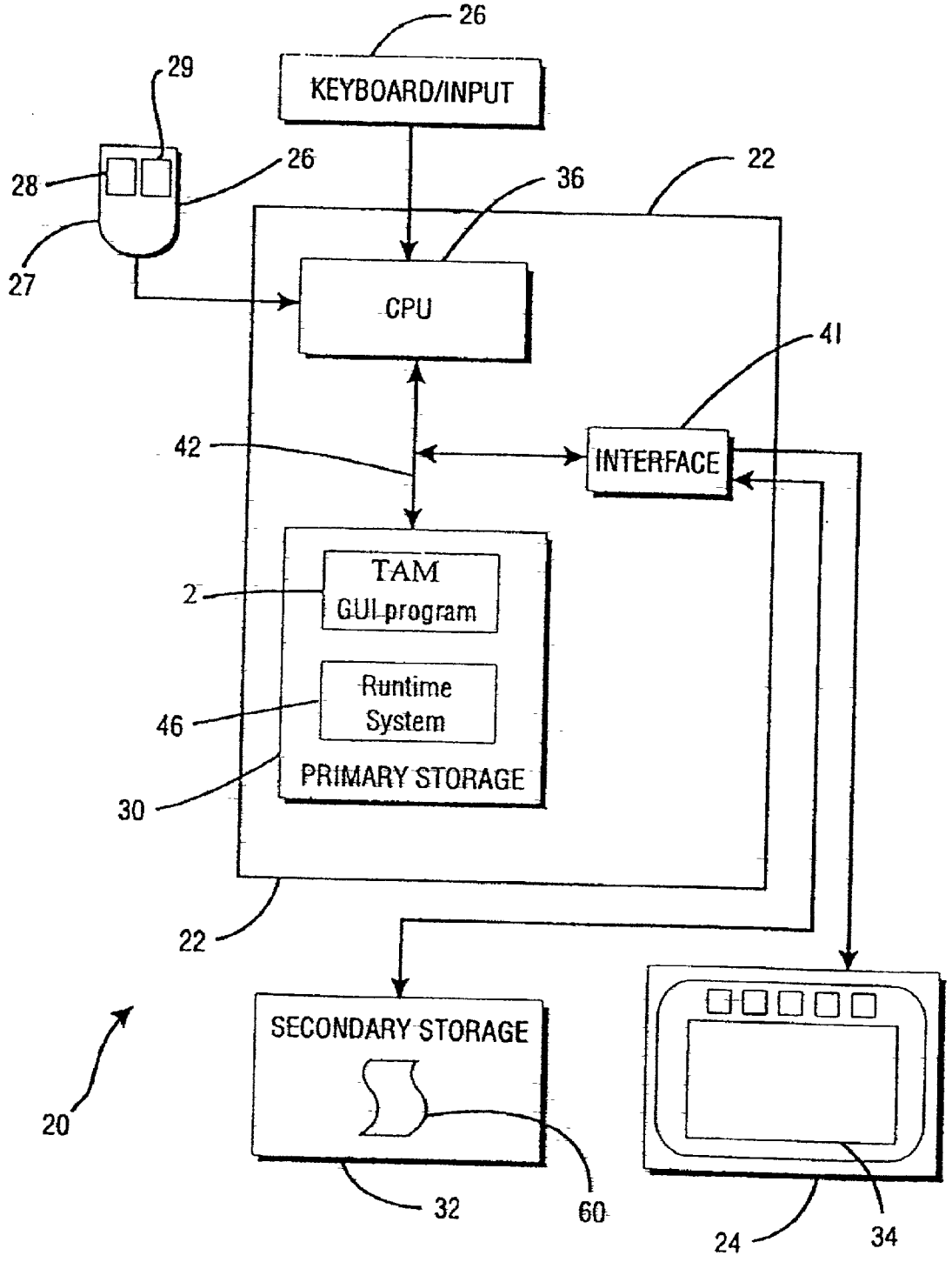

26
KEYBOARD/INPUT
29
28
26
27
22
36
CPU
41
42
INTERFACE
TAM
GUI program
2
Runtime
System
46
PRIMARY STORAGE
30
22
SECONDARY STORAGE
20
32
60
24
34

FIG. 1

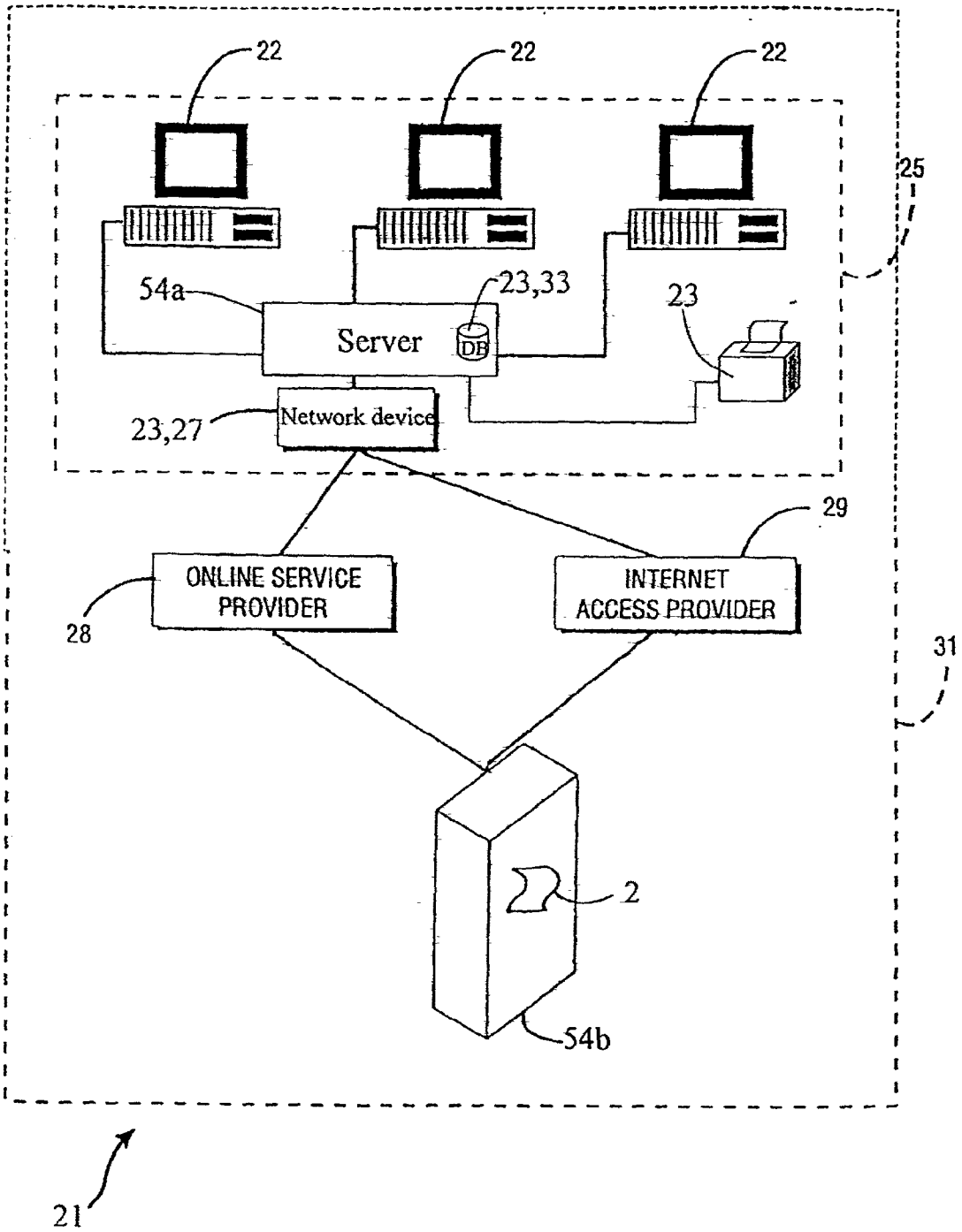

22
22
22
25
54a
23,33
23
Server
DB
23,27
Network device
29
ONLINE SERVICE PROVIDER
28
INTERNET ACCESS PROVIDER
31
2
54b
21

FIG. 2

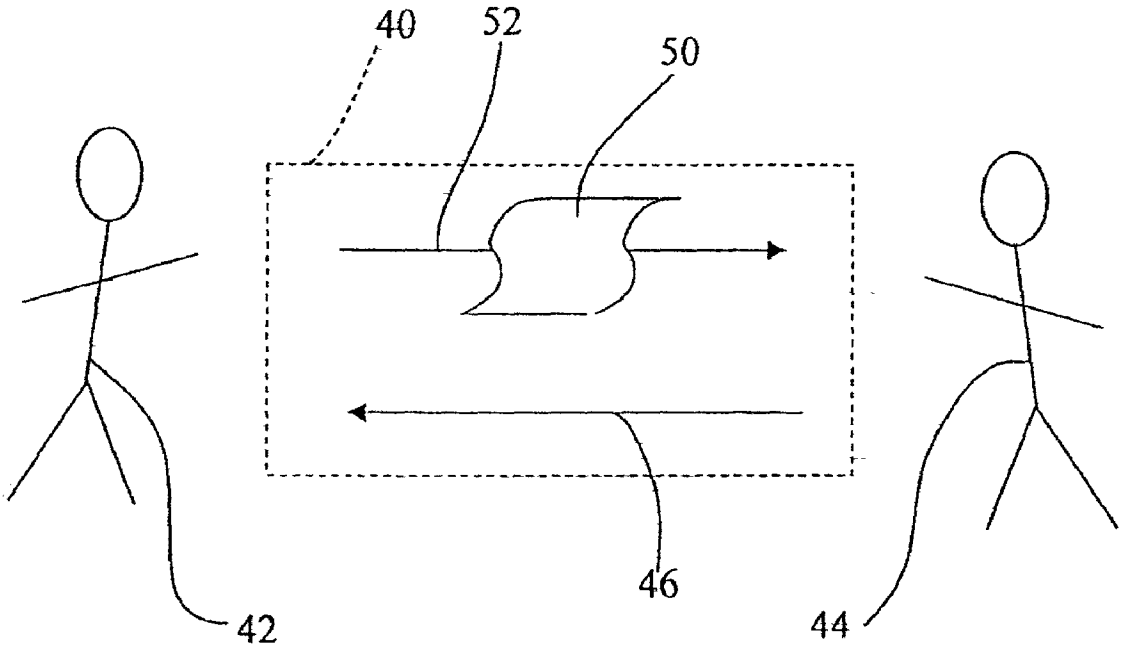


Fig.3

Fig.4

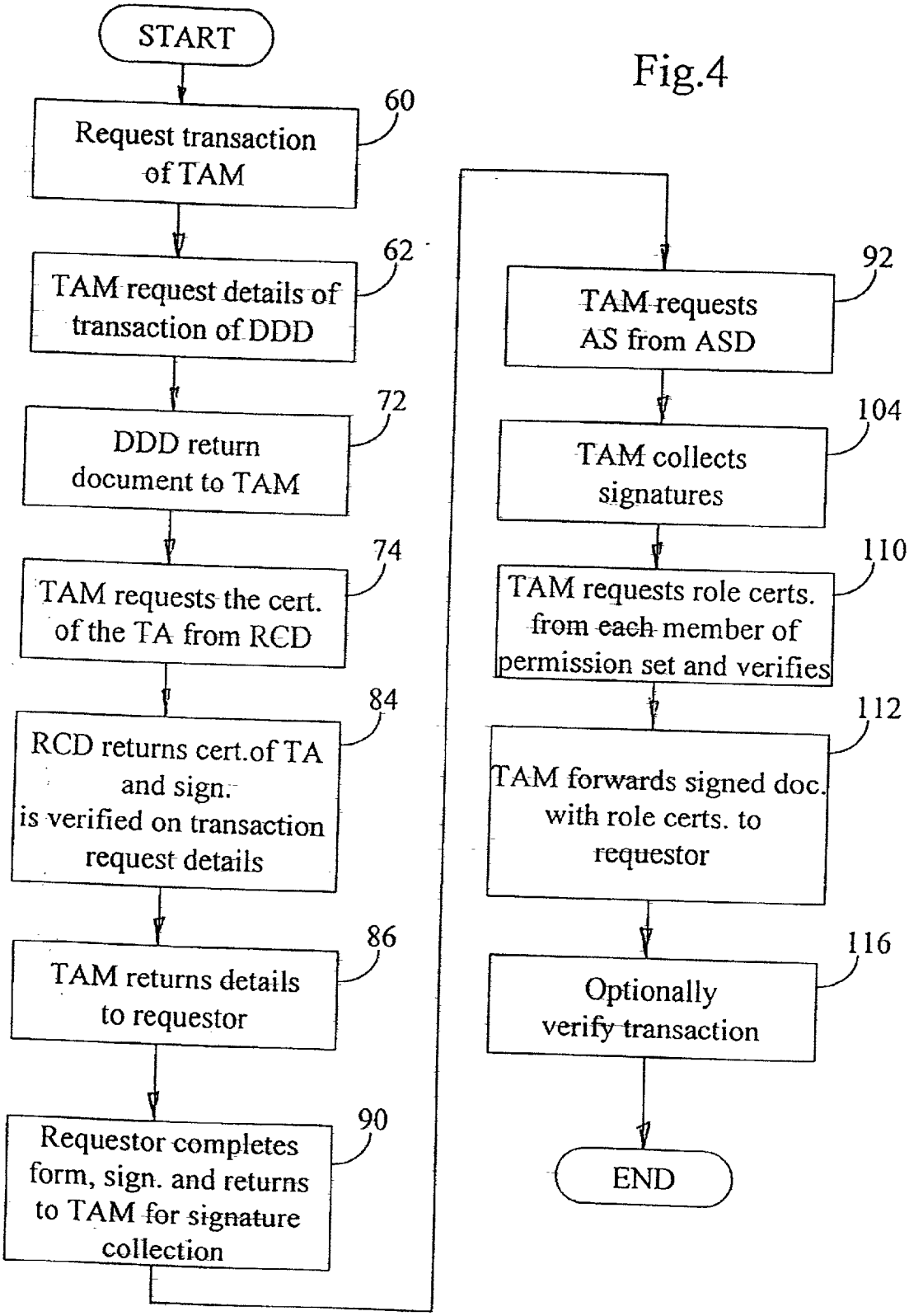

START
Request transaction of TAM
60
TAM request details of transaction of DDD
62
DDD return document to TAM
72
TAM requests the cert. of the TA from RCD
74
RCD returns cert.of TA and sign. is verified on transaction request details
84
TAM returns details to requestor
86
Requestor completes form, sign. and returns to TAM for signature collection
90
TAM requests AS from ASD
92
TAM collects signatures
104
TAM requests role certs. from each member of permission set and verifies
110
TAM forwards signed doc. with role certs. to requestor
112
Optionally verify transaction
116
END

Fig.5

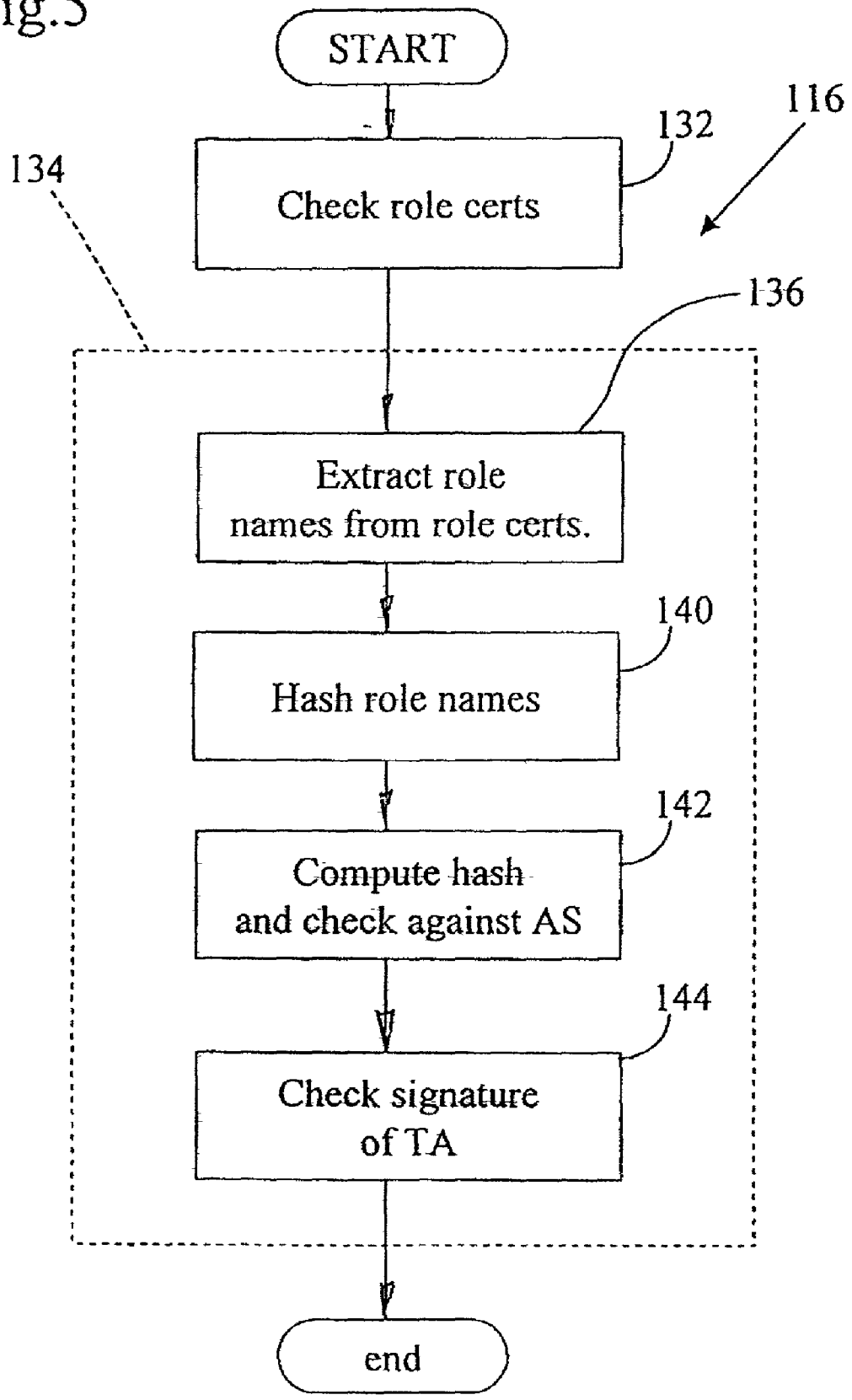

START
116
132
134
Check role certs
136
Extract role names from role certs.
140
Hash role names
142
Compute hash and check against AS
144
Check signature of TA
end

Fig.6

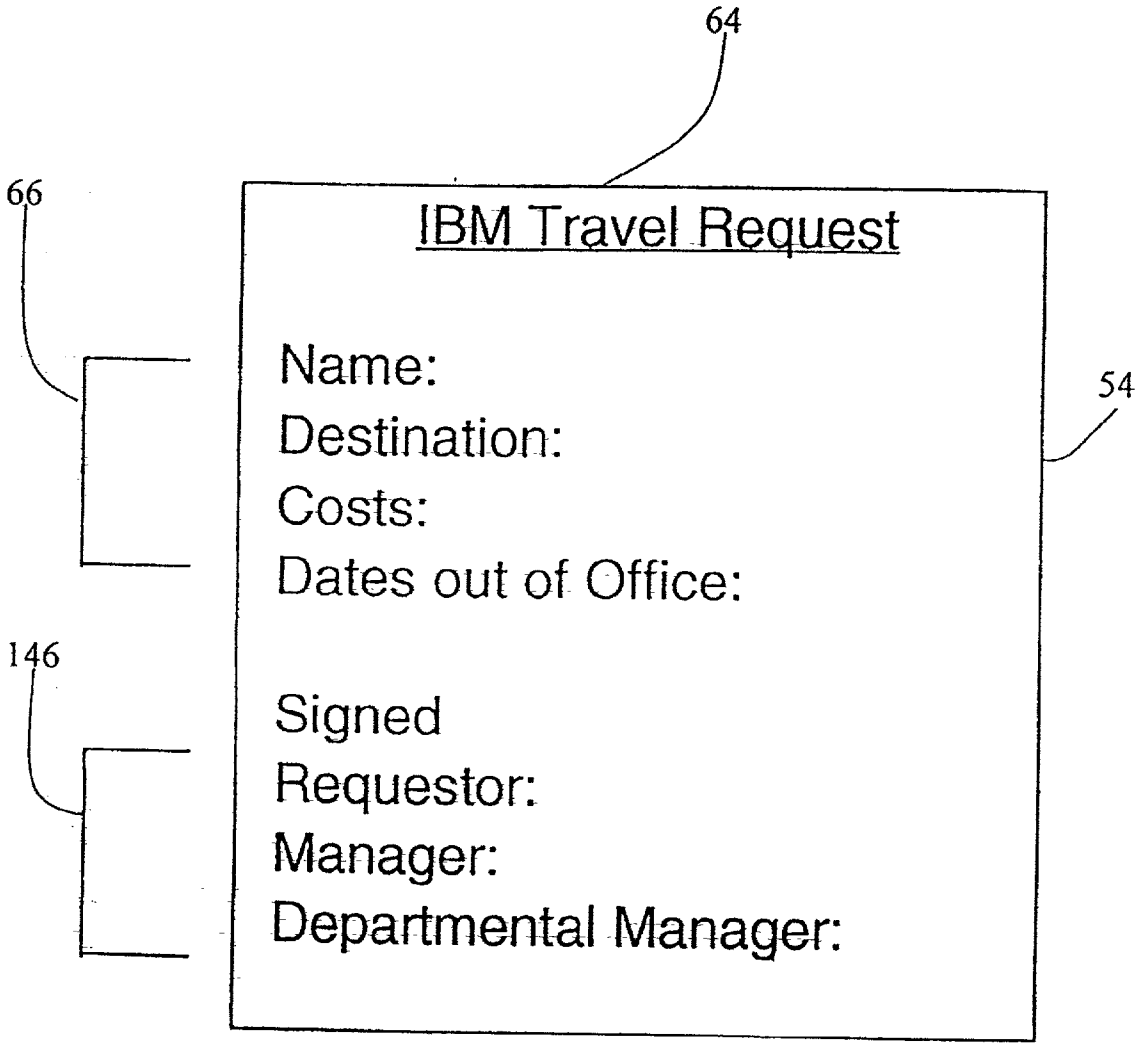
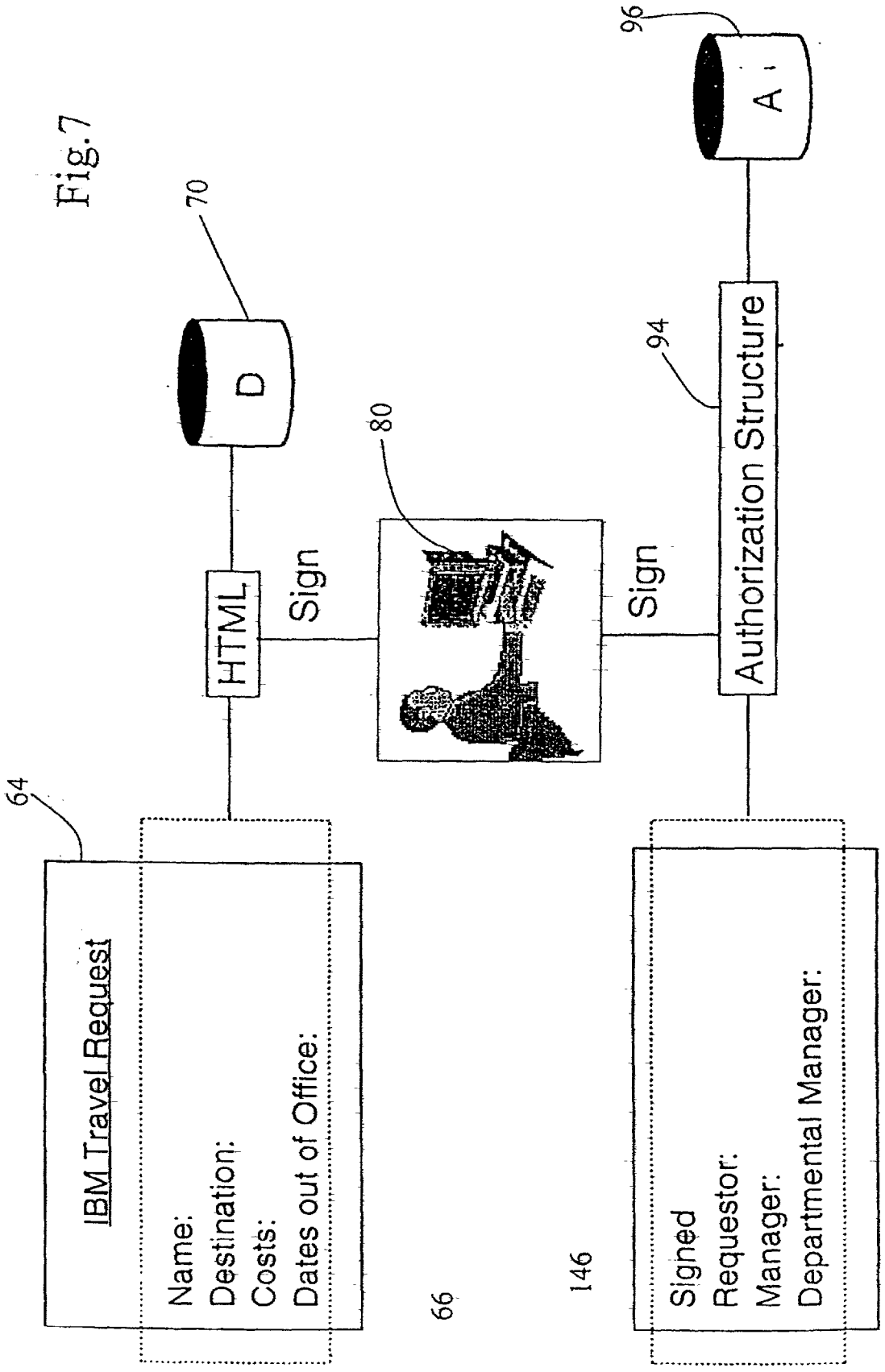

64
66
IBM Travel Request
Name:
Destination:
Costs:
Dates out of Office:
54
146
Signed
Requestor:
Manager:
Departmental Manager:

Fig.7


96
A
70
D
94
Authorization Structure
80
HTML
Sign
Sign
64
IBM Travel Request
Name:
Destination:
Costs:
Dates out of Office:
66
146
Signed
Requestor:
Manager:
Departmental Manager:

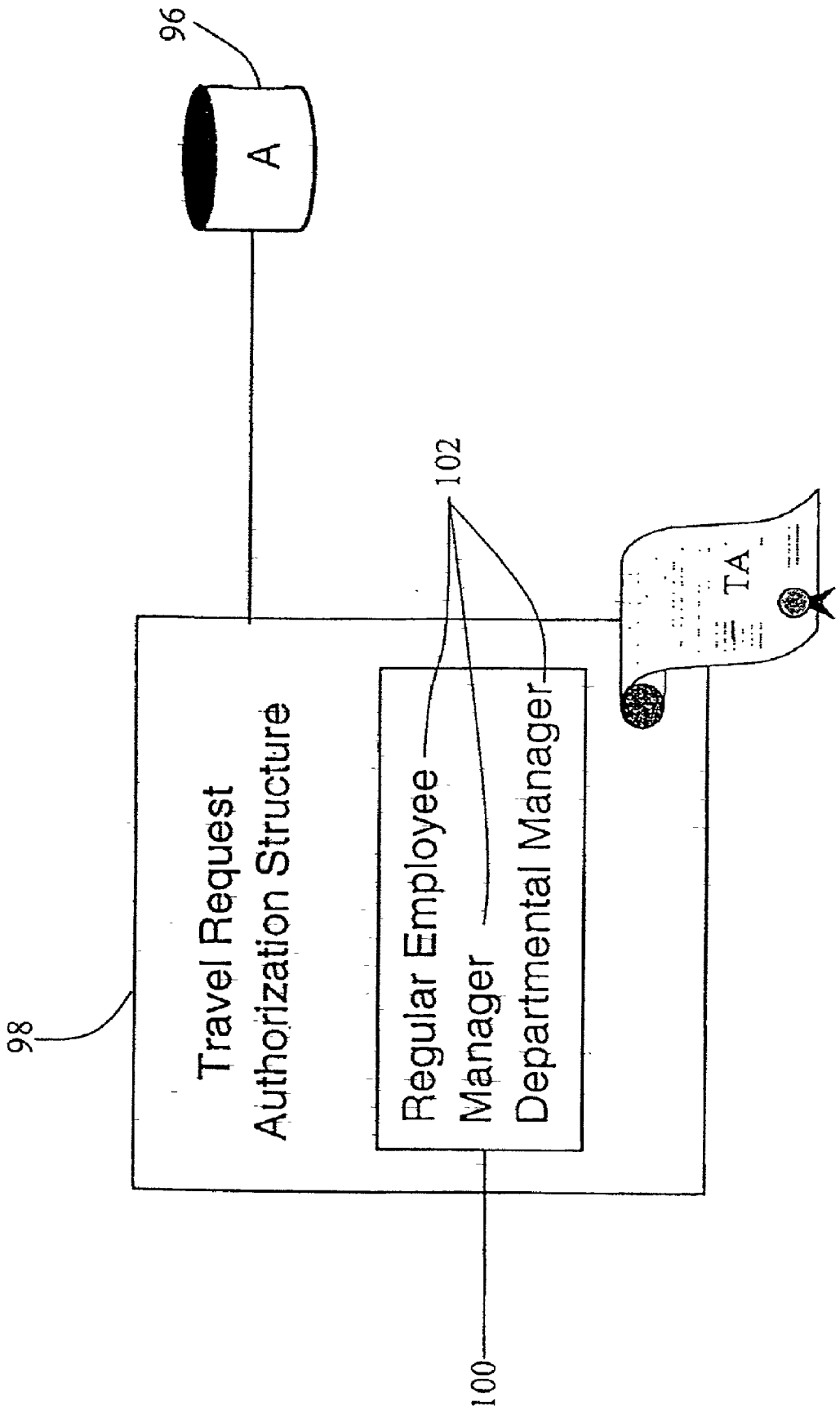

96
A
102
TA
98
Travel Request
Authorization Structure
Regular Employee
Manager
Departmental Manager
100

Fig.8

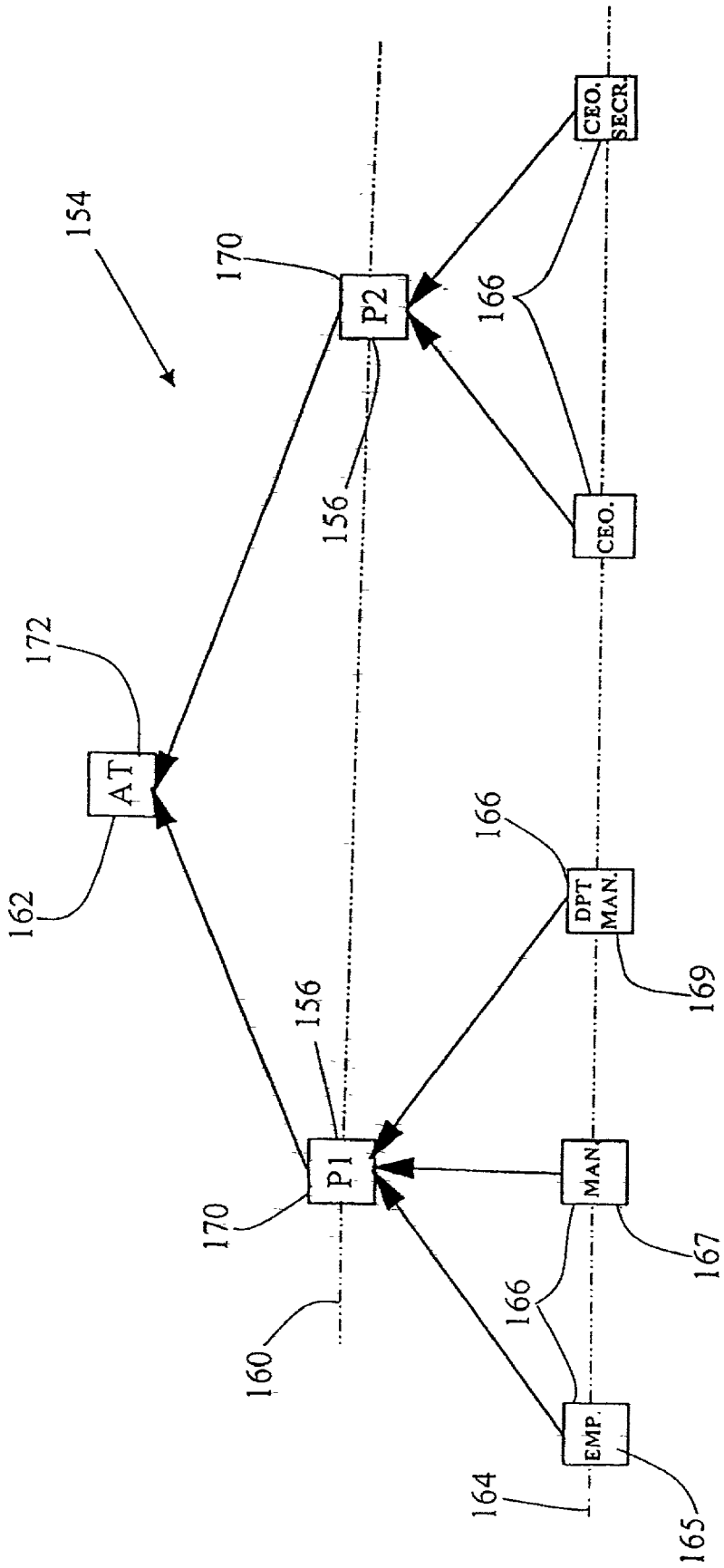

154
170
P2
166
CEO. SECR.
156
CEO.
172
AT
162
166
DPT MAN.
169
156
P1
170
MAN
167
160
166
EMP.
164
165

Fig.9

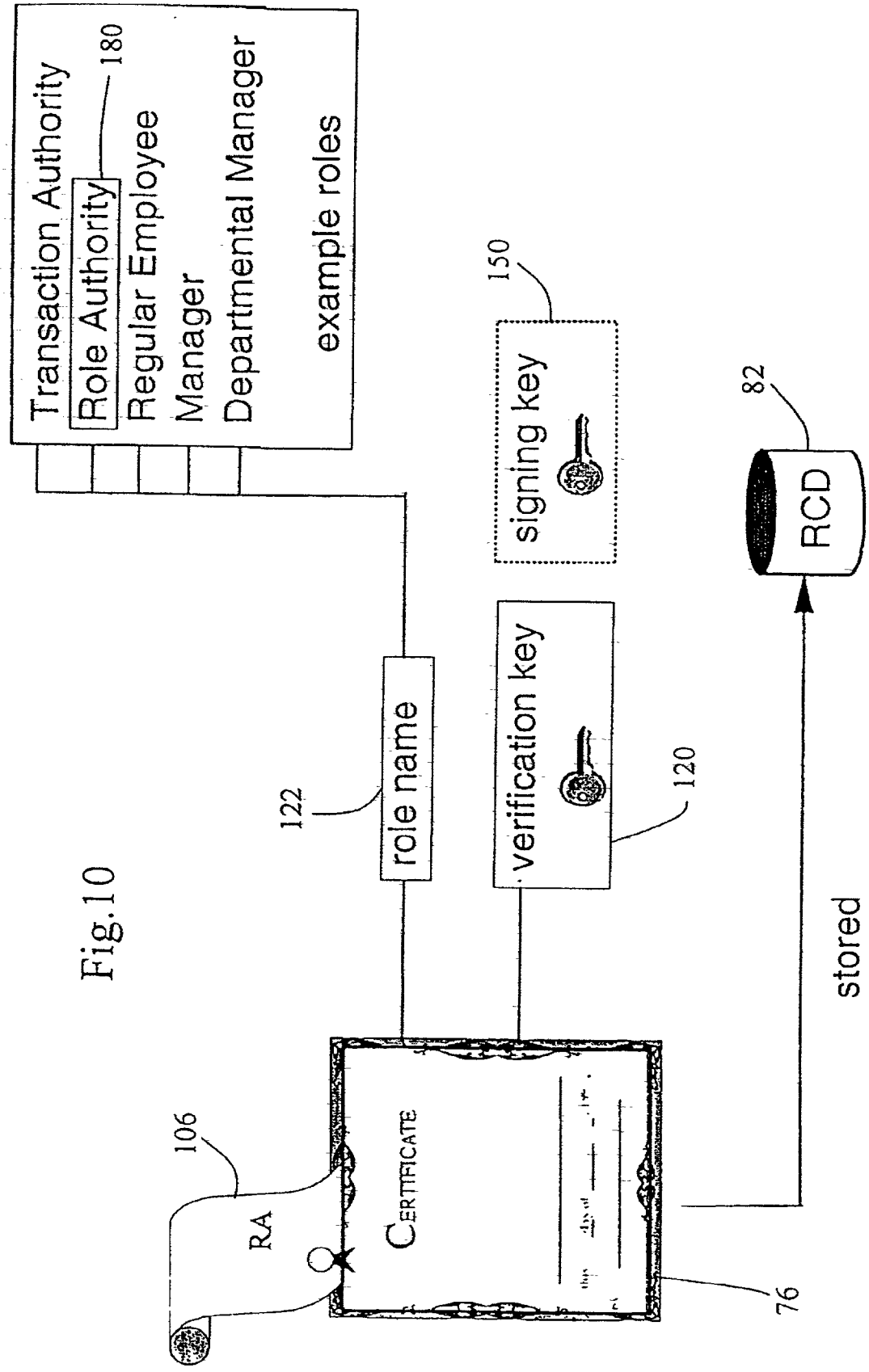

Transaction Authority
Role Authority
180
Regular Employee
Manager
Departmental Manager
example roles
150
signing key
82
RCD
role name
122
verification key
120
106
RA
CERTIFICATE
76
stored

Fig.10

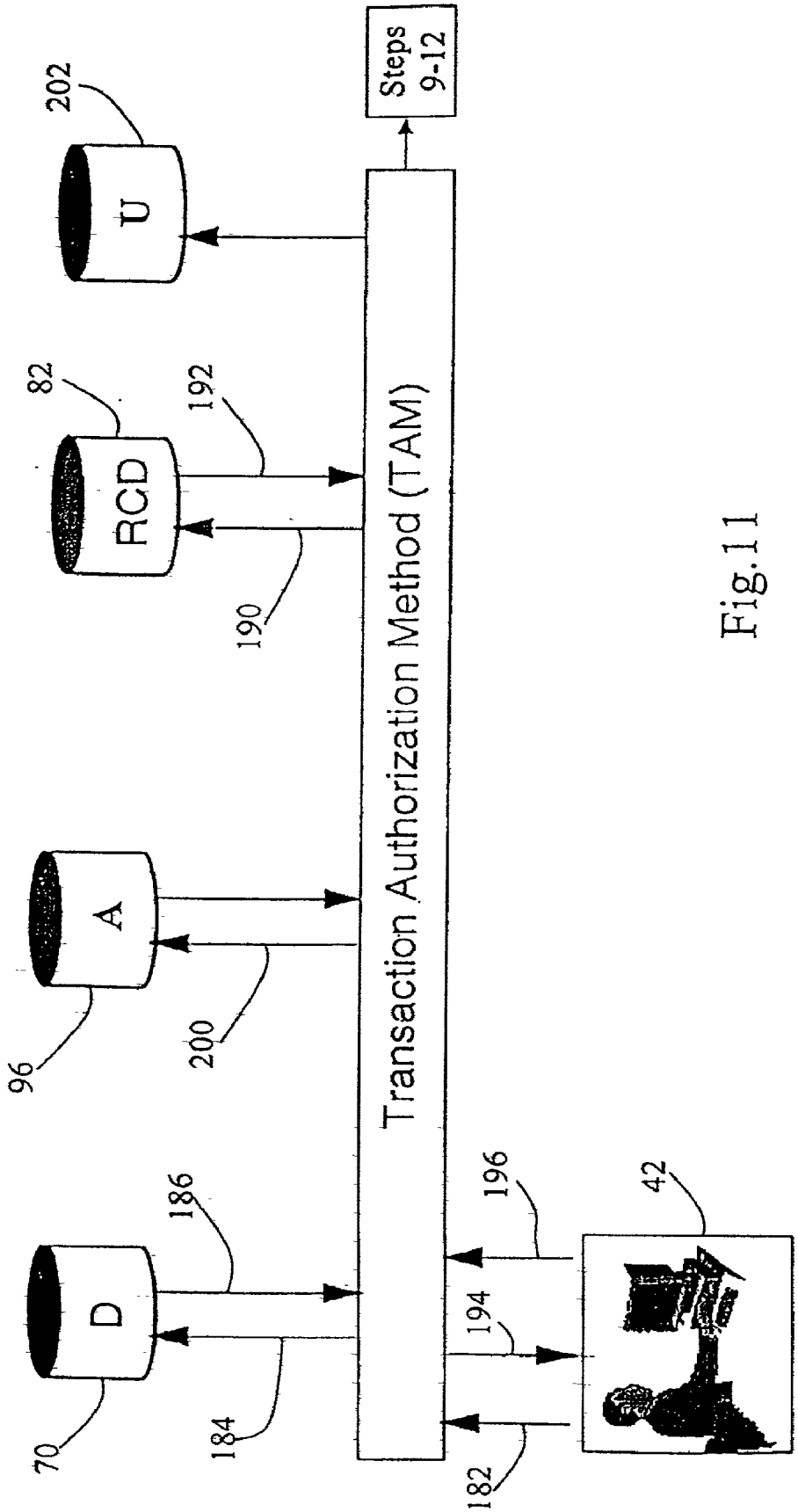

Steps 9-12
202
U
82
RCD
192
190
Transaction Authorization Method (TAM)
96
A
200
186
D
70
184
196
194
42
182

Fig.11

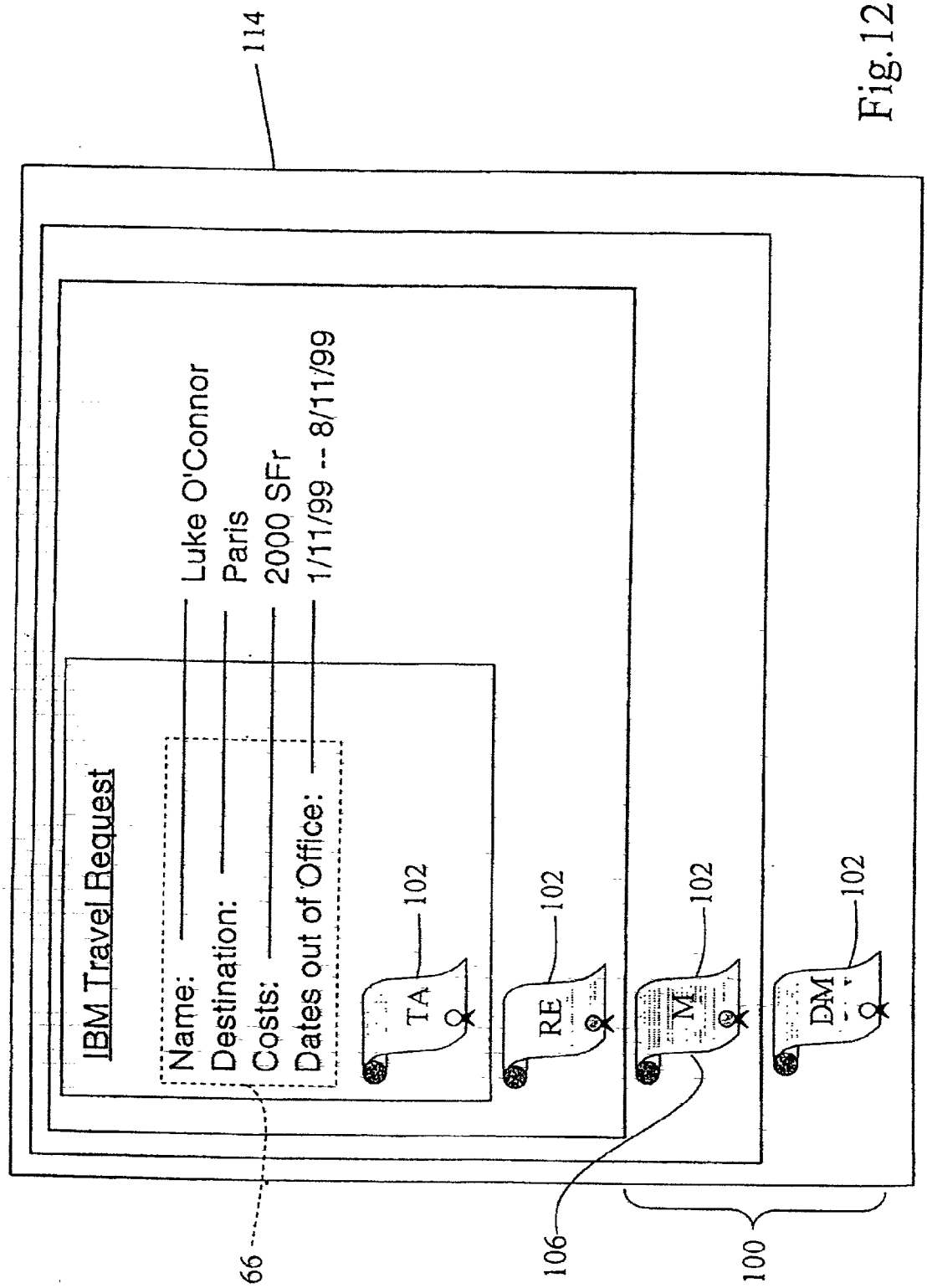

114
IBM Travel Request
Name:
Destination:
Costs:
Dates out of Office:
Luke O'Connor
Paris
2000 SFr
1/11/99 -- 8/11/99
TA
RE
M
DM
102
102
102
102
66
106
100

Fig.12

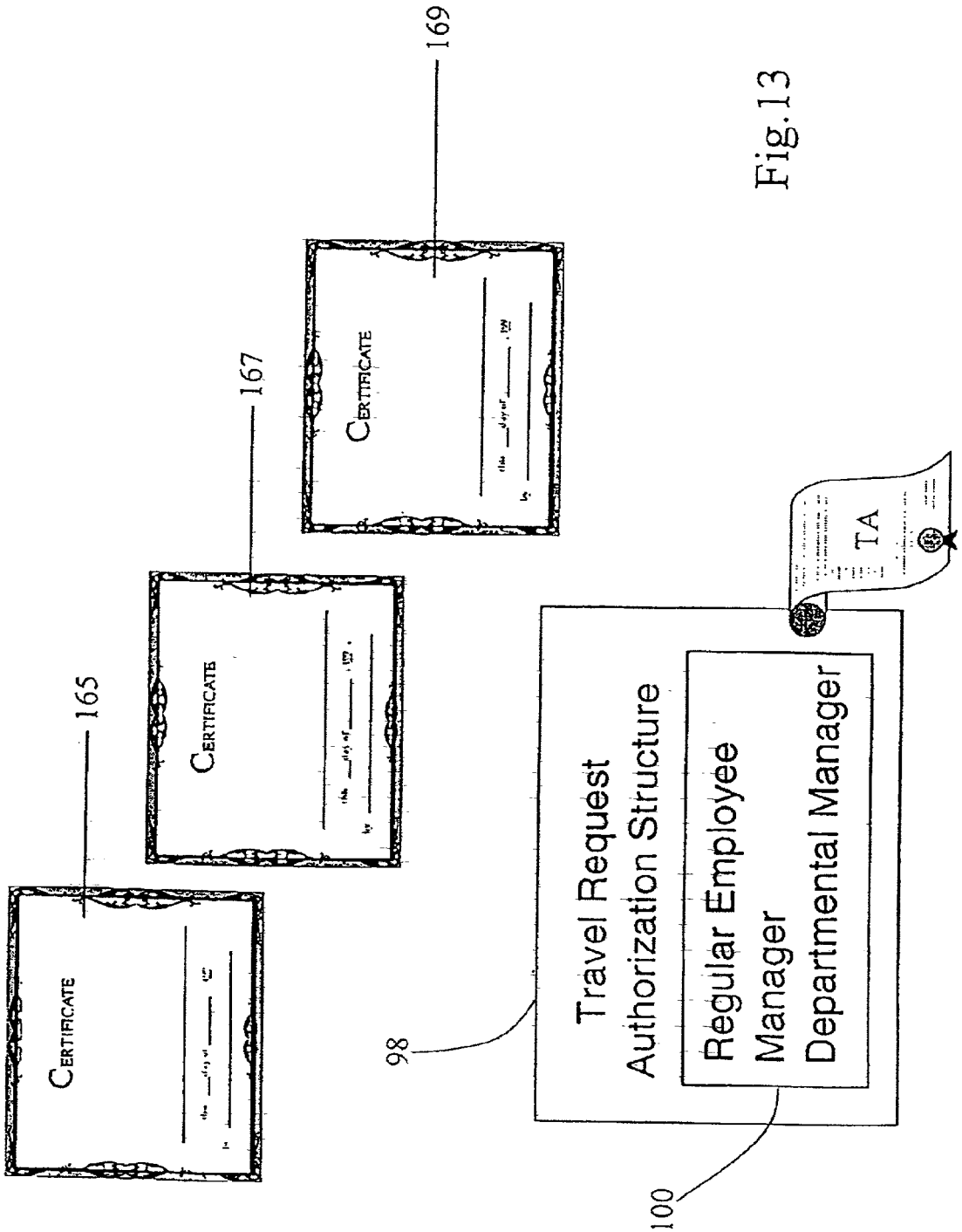

169
167
165
CERTIFICATE
CERTIFICATE
CERTIFICATE
98
Travel Request
Authorization Structure
Regular Employee
Manager
Departmental Manager
100
TA

Fig. 13

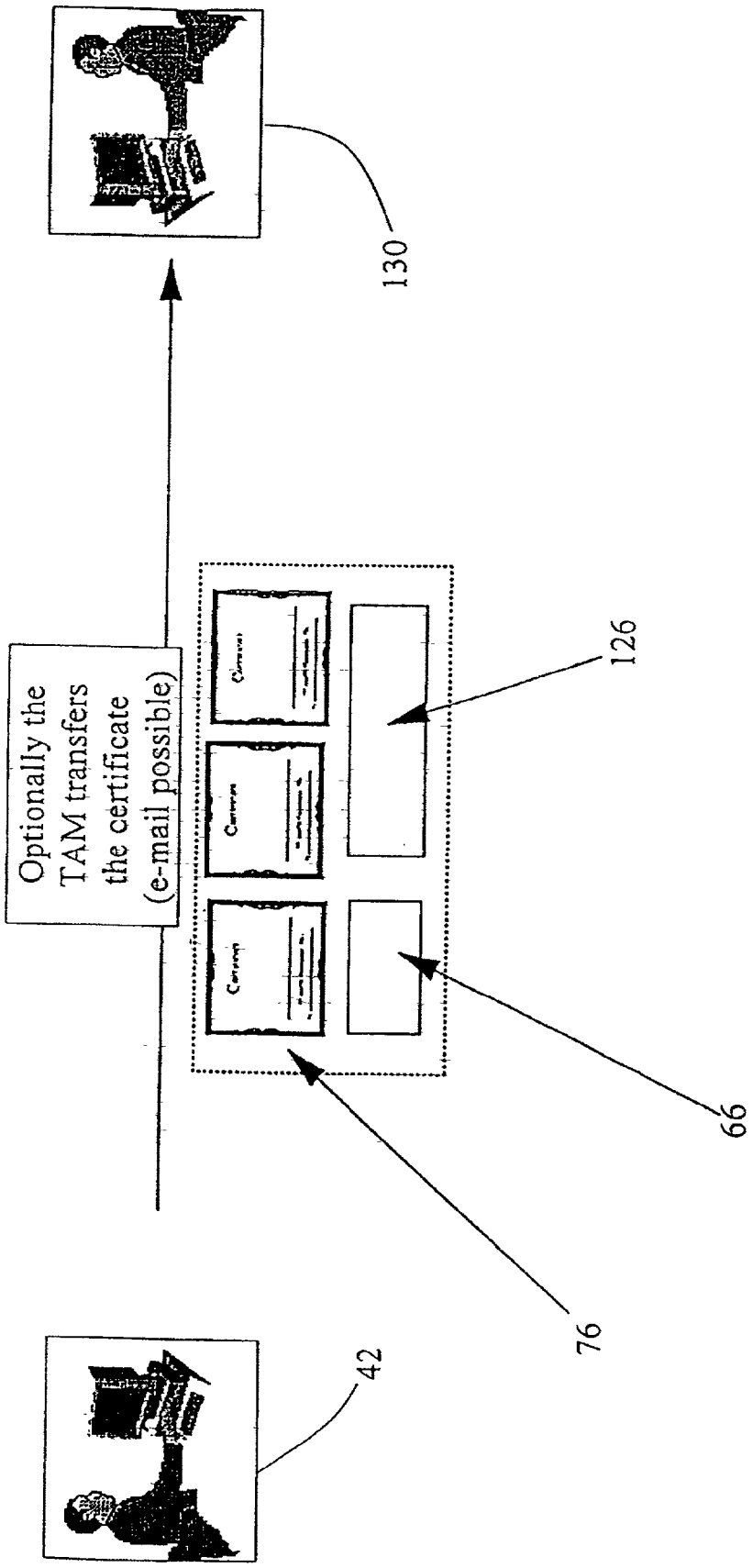

Optionally the TAM transfers the certificate (e-mail possible)
130
126
66
76
42

Fig.14

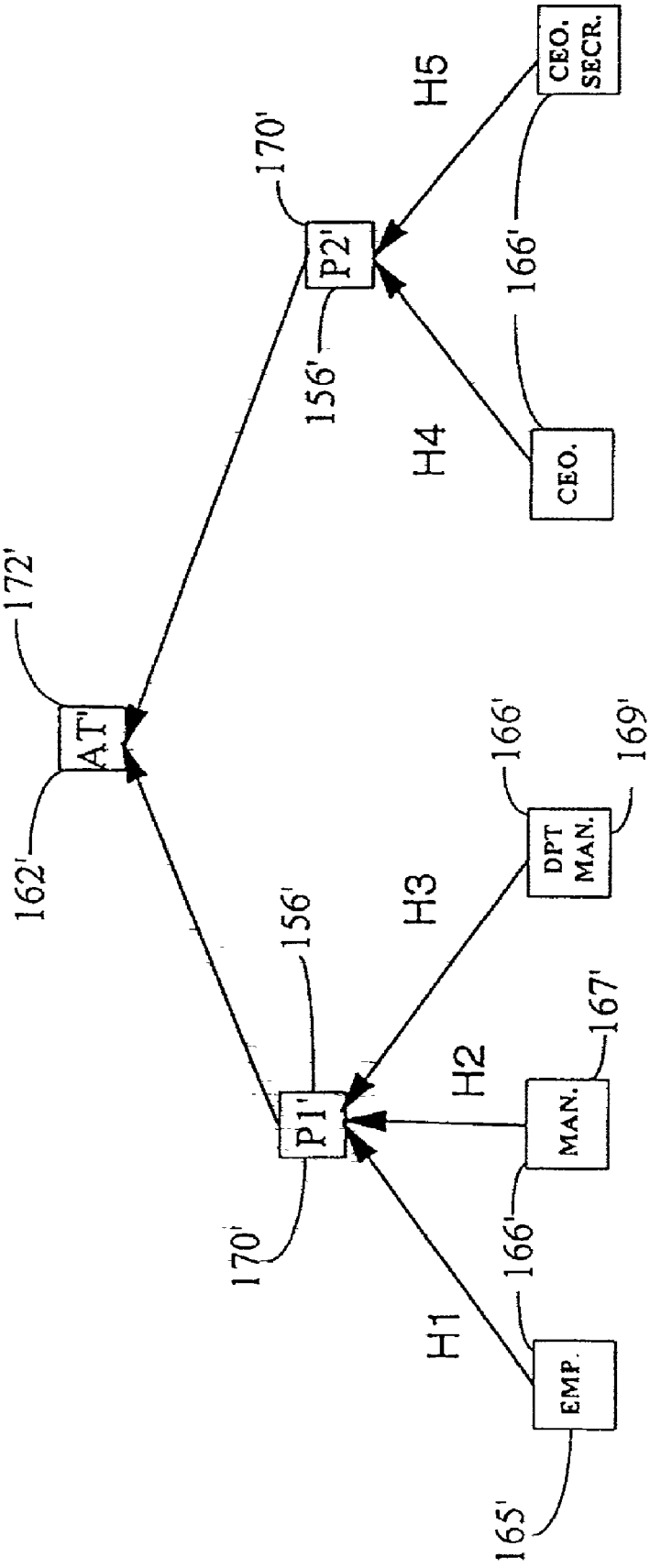

AT'
172'
162'
P1'
156'
170'
P2'
156'
170'
H1
H2
H3
H4
H5
EMP.
MAN.
DPT MAN.
CEO.
CEO. SECR.
165'
166'
167'
166'
169'
166'

Fig.15

METHOD FOR INTER-ENTERPRISE ROLE-BASED AUTHORIZATION

FIELD OF THE INVENTION

[0001] This invention relates to e-commerce transactions, and, more particularly, to a method of both authorizing and verifying the authorization of transactions between enterprises over both public and private networks.

BACKGROUND OF THE INVENTION

[0002] Large-scale deployment of e-commerce solutions between various enterprises over public networks requires careful consideration of security issues. This is best explained through an example.

[0003] Two companies, company A and company B, have a formal agreement for making business transactions (i.e., any legally binding action between persons or organizations), such as an offer, an order or a cancellation. The possible set of transaction types between A and B may be denoted by T(A,B)={T1, T2, . . . , Tn} where for example T ϵ T(A,B) may denote

T→"purchase *X* units of product *Y* at price *P* per unit".

[0004] The transaction types denoted by the set T(A, B) may be assumed to be general, and at the actual time when the particular transaction takes place, additional details beyond those given in the transaction descriptions of T(A, B) must be provided. For example, for transaction T, the requester will supply values for X, Y, and P, which are expected to vary over time.

[0005] The problem of specifying the set of transactions T(A, B), how they will be performed, the data exchanged and so on, could be solved using Electronic Data Interchange (<<EDI>>) syntax, such as in ISO 9735, available at http://www.r3.ch/standards/edifact/index.html. Further, these companies must coordinate over the Internet to fulfill their general transactions as specified in the set T(A,B).

[0006] A typical situation would be for a user UA of company A to receive a transaction of type T ϵ T(A,B) from a user UB, that purports to be under the control of company B. Let us assume that UA is presented with a request from company B for company A to make X=1000 units of product Y at price P=$1 per unit and further that the user operates through software operating through a public network. Since the request originates from a public network, there are at least three security issues that UA may consider: (1) should the details (X, Y, P, UA, UB) of the transactions be confidential and encoded for integrity? (2) how does one verify that the user UB requesting the transaction is in fact controlled by company B? and (3) even if it is known that the user UB requesting the transaction is employed by company B, it is not clear how one verifies that UB is in fact authorized to request such a transaction for the given values of X, Y and P.

[0007] The first two points can be addressed using standard security protocols and cryptographic algorithms, as described in A. Menezes, P. van Oorschot, and S. Vanstone; *Handbook of Applied Cryptography*, CRC press, 1996. In particular, with public key cryptography each user Ux can be issued with one or several certificates (such as those described in ISO/IEC 9594, Information Technology—Open Systems Interconnection—The Directory: Authentication Framework, 1993) that can be used to demonstrate their identity through the use of digital signatures.

[0008] If UA and UB are acquainted personally then that existing trust relationship may be sufficient for UA to accept the request from UB as authorized, and this is how many inter-enterprise transactions are currently conducted. In this case, UA and UB have established some trust relationship, either specifically for the purpose of conducting future transactions, or perhaps the trust has been gained by successful previous transactions. However, general e-commerce will bring together people and companies who will have no prior business or trust relationships, and the transaction then must somehow be 'self-authorizing'. Traditionally authorization to data, applications, resources, or more generally simply objects, is administered using some form of access control. See D. E. Denning; *Cryptography and Data Security*. Addison—Wesley Publishing Company, 1982. In its most general form, there exists an access control matrix M that explicitly lists the access rights each user has with respect to each object O. As there may be many users Ui and objects Oj, the access control matrix M can be difficult to manage.

[0009] Perhaps the most common type of authorization is for there to be a general written document/form describing a transaction T, where certain details are provided by the requester at the time of the request, and the requester is then required to collect a set of handwritten signatures on the paper form, from one or several people who are able to approve transactions or requests of type T. For example, T may be a travel request form, which requires that the destination, duration of stay, expected costs and methods of transport be provided. The requester fills in these details, signs the request, and then takes the form to various superiors for their signatures in the appropriate places provided on the form. Typically the places in the form where a signature is required are labeled by the role of the people whose signatures are required, such as manager, department head or CEO.

[0010] This form of authorization is called the form-signature model, or authorization by co-signatures, or co-signing data. For example, the travel request transaction (T='travel request') may require the signature of the requester, the requester's manager and then the department head of the requester. Once the required signatures have been collected, the requester uses the signed document to authorize the transaction, say to have a travel agent book flights or hotels. Usually the travel agent is not concerned with verifying the details of the travel request, other than general checks such as the return date is after the departure date, or that some threshold of expense is not exceeded. What is of importance to the travel agent is the set of signatures accompanying the request, and the roles represented by these signatures. For many office tasks that do not involve significant amounts of funds, the form-signature model is adequate for granting task authorization. However, where more significant amounts of funds or resources are committed by the transaction, it becomes important to be certain that each signature is both authentic, and that the collection of signatures does, in fact, bind the company. In these cases, it becomes necessary to obtain direct approval of every transaction from an enterprise authority (i.e., Transaction Administrator such as the President, comptroller, or

other officer) for confirmation that the lower level employees had authority to authorize the transaction.

[0011] A form-signature model for e-commerce includes: (1) an electronic representation of the task and the information required to perform the task (such as dates, costs, names), (2) a signature mechanism, and (3) a mechanism to relate the signatures accompanying the electronic task data to privilege for granting authorization for the task. Generally speaking, (1) and (2) can be solved directly using current methods and technology, while (3) has not yet be adequately addressed. With respect to (1) and (2), paper-based forms can be represented electronically as HTML or word-processor documents, and for a task T, let D(T) denote the electronic form/template of task T. If T is a 'travel request' then for example D(T) may be a HTML document requesting details of the trip to be taken, and there will also be a list of roles where users acting in these roles must sign the travel request details. Also there are several schemes for providing digital signatures, such as RSA or DSS, so the basic tools to implement the form-signature model in e-commerce are available. The more difficult part in the e-commerce form-signature model is to determine or verify that the set of collected signatures implies authorization for the task.

[0012] If a user U digitally signs data, it is implied that U has a public key Pub(U) and a private key Pri(U) such that Pub(U) is stored in a certificate, which we will denote as Cert(U). The certificate Cert(U) is stored in a public database or directory, so anyone may retrieve it and verify a signature purportedly produced by U with Pri(U). The certificate Cert(U) contains one or several names/identifiers for U, so U can be uniquely identified as the user who produced the signature. However in considering if another user is verified to request transaction T by examining a set of signatures on D(T), the important aspect is not so much who produced each signature but whether they have the authority to authorize T.

[0013] Therefore, what is needed is a method that frees the enterprise authority from having to verify every transaction and which enables efficient authorization and verification of authorization of e-commerce contracts, using standard security or cryptographic protocols, over an insecure public network. Still further, what is needed is a method for performing inter-enterprise authorization that reveals minimal information about the decision structures of the respective companies.

SUMMARY OF THE INVENTION

[0014] A transaction authorization method is provided which operates over a computer network comprising a plurality of interconnected computers and a plurality of resources, each computer including a processor, memory and input/output devices, each resource operatively coupled to at least one of the computers and executing at least one of the activities in the process flow. The method assembles an electronic authorization of a transaction in a manner that is verifiable by extracting and verifying whether role certificates of at least one type, associated with the authorization, are themselves authentic. The method eliminates the need of having to authorize each and every signature on a transaction individually by providing an authorization structure based on roles, this structure being accessible on a public network for verification that the transaction is authorized.

[0015] The method is applicable in both an intra-enterprise and an inter-enterprise context, because it makes anonymous authorization decisions based on roles, represented by anonymous role certificates. In this manner, the identities of the employees need not be divulged when verifying the authenticity of the transaction.

[0016] Further, the method uses an authorization tree for a particular transaction that determines what combination of roles can authorize transactions of that type.

[0017] In another feature involving inter-enterprise authorization, a hashed version of the authorization tree is used, thus providing proof that a given user is authorized to perform a transaction while revealing minimal information about the approval structures of the company. In this manner, the method allows verification of a company's decision structures in such a manner as to obscure the details of this structure.

[0018] An object of the invention is to promote e-commerce by providing a convenient and computerized means of ensuring that transactions are properly authorized and therefore enforceable.

[0019] Another object of the invention, where the hash table is used, is to reduce space requirements and to obscure the decision procedure information in the authorization tree while still permitting the transactions to be authorized, thus making the method particularly useful for intra-enterprise transactions.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] The invention will now be described in greater detail with specific reference to the appended drawings wherein:

[0021] **FIG. 1** is a block diagram of a computer system of the invention;

[0022] **FIG. 2** is a schematic diagram of a network encoded with the method of the invention;

[0023] **FIG. 3** is a schematic diagram of a transaction;

[0024] **FIG. 4** is a detailed flow diagram of the method of the invention;

[0025] **FIG. 5** is a flow chart of a verification submethod of the invention;

[0026] **FIG. 6** is a schematic diagram of a travel request document used in the method;

[0027] **FIG. 7** is a block diagram showing the transaction authority of the method;

[0028] **FIG. 8** is a block diagram showing the authorization structure of the method;

[0029] **FIG. 9** is an authorization tree for a travel request;

[0030] **FIG. 10** is a block diagram showing an interaction of the method with role certificates;

[0031] **FIG. 11** is a block diagram showing the interaction of the TAM with various databases in the method;

[0032] **FIG. 12** is a schematic diagram of the completed travel request;

[0033] **FIG. 13** is a schematic diagram showing the role certificates in the travel request;

[0034] **FIG. 14** is a schematic diagram showing the transfer of the request to the verifier; and

[0035] **FIG. 15** is a hash of the tree of **FIG. 9**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0036] Referring now to **FIG. 1, a** Transaction Authorization Method ("TAM") **2** provides a means of ensuring the validity of contracts **4** in e-commerce by constructing such contracts in a manner such that their validity can be easily verified.

[0037] The TAM **2** has a message exchange mechanism that operates within the distributed workflow management system **6**. The method **2** has the properties of (1) being accessible by users **8** to authorize requests **10**; (2) having access to several databases **70, 82, 96** or **202** (shown in **FIG. 11**); and (3) contacting users to request signatures **18**.

[0038] The TAM **2** operates on a computer system **20** in a distributed system **21** over a computer network **25** and/or **31** (shown in **FIG. 3**) comprising a plurality of interconnected computers **22** and a plurality of resources **23**. The TAM **2** is encoded on computer-readable media and operates on the computer system **20** and/or between computer systems and one or more servers **54***a* or **54***b* (shown in **FIG. 2**) on an intranet **25** or the Internet **31**.

[0039] The computer system **20** typically includes a computer **22**, a display device **24**, an input device **26** such as a keyboard, a primary storage device **30** and a secondary storage device **32**. After loading of software encoded with the TAM **2** of the invention or after accessing the server **25** or **54** through a browser such as Internet Explore 5.0, as the case may be, the display device **24** displays a graphical user interface ("GUI") **34** for facilitating the display of text and graphics associated with the method to the user. Display devices **24** include printers and computer display screens such as a CRT, LED displays, LCDs, flat screens, screen phones, and projectors. Input devices **26** are numerous and include keyboards and pointing devices such as a mouse **27** having a left mouse button **28** and a right mouse button **29**, a trackball, lightpens, thumbwheels, digitizing tablets, microphones using voice recognition software, and touch screens and pads.

[0040] Each resource **23** is operatively coupled to at least one of the computers .**22** and executes at least one of the activities in the process flow of the method **2**. Resources **23** include, but are not limited to, printers, databases, special-purpose servers, security devices, modems, etc.

[0041] The GUI **34** provides input fields for data input and control of the TAM **2**, as well as an output window for displays of status and other information, which facilitates management and operation of the workflow system. The TAM **2** accesses a database **33** including information associated with transactions, discussed in detail below.

[0042] The computer **22** includes a CPU **36** as well as other components with which all who are skilled in the art are familiar. For a detailed discussion of these components and their interaction, see U.S. Pat. No. 5,787,254, the content of which is incorporated by reference. The secondary storage **32** supports the TAM **2**, preferably HTTP-compliant, as well as a number of Internet access tools. The CPU **36** fetches computer instructions from primary storage **30** through an interface **41** such as an input/output subsystem connected to a bus **42**. The computer **22** can be, but is not limited to, an "IBM APTIVA" computer, a product of International Business Machines Corporation of Armonk, N.Y., or any computer compatible with the IBM PC computer systems based on the X86 or Pentium(TM) series processor of Intel Corporation or compatible processors, or any other suitable computer. The CPU **36** utilizes an operating system that, depending on the hardware used, may be DOS, "WINDOWS 3.X", "WINDOWS XXXX", "NT", "OS/X", "AIX", "LINUX", or any other suitable operating system. The CPU **36** executes these fetched computer instructions. Executing these instructions enables the CPU **36** to retrieve data or write data to the primary storage **30**, display information, such as the statistical displays of the TAM **2**, on one or more display devices **24**, receive command signals from one or more input devices **26**, or transfer data to secondary storage **32** or even other computer systems which collectively form a computer network **25** (shown in **FIG. 2**). Those skilled in the art understand that primary storage **30** and secondary storage **32** can include any type of computer storage including RAM, ROM, application specific integrated circuits ("ASIC") and storage devices that include magnetic and optical storage media such as a CD-ROM.

[0043] Referring now to **FIG. 3** there are many classes of transactions **40** that are to be carried out online in the course of conducting e-commerce. In the context of this disclosure, each transaction **40** takes place between a requester **42** and a verifier/value provider **44** The requester **42** desires a product or service **46** and the value provider **44** wishes to be sure that the e-documentation **50**, upon which the requester's request **52** is based, is properly authorized. Thus, the value provider **44** wishes to verify the authenticity of the document **50**. In the most general context, the requester **42** and verifier **44** may or may not be employed by the same company.

[0044] For example, the document **50** associated with the request **52** may be a contract for products or services, such as a travel request document **54** (shown in **FIG. 6**) from an employee of the requesting company to the company's travel agent, or from the employee to the financial officer of the same company to determine if the required funds for the travel are available.

[0045] Now referring to **FIG. 4**, in which a more detailed flow diagram of the method is shown, the TAM **2** executes the following steps. In a first step **60**, an employee **62** requests a transaction **40** from the TAM **2**. In a second step **62**, the TAM **2** requests the HTML representation **64** of details **66** of the transaction **40** from the Digital Document Database **70** (shown in **FIG. 7**). In a third step **72**, the Digital Document Database **70** returns the HTML representation **64** of the transaction details **66** to the TAM **2**. In a fourth step **74**, the TAM **2** requests the role certificate **76** of the TA **80** from a Role Certificate Database **82** comprised of <<anonymous>> role certificates (the anonymity is implied since the user's name is not included in the certificate), including the role certificates of the TA **80** (this is discussed in more detail below). In a fifth step **84**, the Role Certificate Database **82** returns the certificate **76** of the TA **80** and the TAM **2** verifies

the signature **126** of the TA on the HTML representation **64** of the transaction request details **60** returned from the Digital Document Database **70**. In step six **86**, the TAM **2** returns the HTML transaction details **66** to the requester **42**. In step seven **90**, the requester **42** views the HTML representation **64**, completes the details **66** specified (e.g., name, destination, costs, etc.), signs the completed HTML representation **64** and returns the signed HTML representation to the TAM **2** to collect any remaining signatures **106**. In an eighth step **92**, the TAM **2** requests the AS **94** for the transaction from the Authorization Structure Database **96**. The returned AS **94** is pre-signed by the TA **80** and the signature is verified by the TAM **2**. The TAM **2** chooses a permission set **100** of role names **102**, and a collection of users to contact to sign in these role names. In step nine **104**, the TAM **2** forwards details **66** of the transaction request **52** with the signature **106** of the regular-employee requester **42** to others having roles corresponding to the chosen permission set **100** and collect signatures of each role indicated in the permission set **100**. For example the signature of a manager and a department manager is collected each signing the document **64** in his respective role. In step ten **110**, the TAM **2** requests the role certificates **76** for each member of the permission set **100** and respective signature. In step eleven **112**, the TAM **2** forwards the document **54** including the signatures **106** and role certificates **76** to the requester **42**. Thus, a digital document **114** is created including all the authorization details **66** required in order to confirm the validity of the transaction **40**. In step **116**, optionally, the method **2** verifies the signed document **114**.

[**0046**] Referring now to **FIG. 9**, in the method **2**, the anonymous role certificate **76** is an association between a signature verification key **120** and a role **122**. This differs from the standard certificate described in ITU-T X.509 (1997 E)(hereinafter <<X509>>), which is an association between a signature **106** verification key **120** and a name (not shown). More accurately stated, X509 is the association between a public key and a name, where the public key can be used for both encryption and signature verification. The method **2** of the invention, however, is not concerned with users performing encryption in the capacity of a role **122**, but rather is concerned with users producing signatures **106** in the capacity of a role. The certificate **76** will be anonymous by not having any linking information to owner of the certificate. The 'owner' of a certificate Cert is implicitly defined as the user who has the private key that corresponds to the public key embodied in the certificate.

[**0047**] A role certificate **76** plays an important role in the method **2**. It is assumed that within any company C there exists a set of well-defined roles RC={R1, R2, . . . , Rm}, and that each user U in the company C is assigned one or several roles UR $\subset$ RC. For the purposes of the method **2**, it is assumed that each user has a X.509 public key certificate CertCA(U) that contains their name, public key and other fields, signed by some local certificate authority CA. As X.509 certificates contain extension fields for general information such as an e-mail address, alternative names, and policy information for example, it is possible that a designated role **122** could be included as an extension field. However the role **122** and owner of the certificate are linked explicitly since the certificate contains a name field. An IETF working group is also currently developing the concept of an attribute certificate (AC) (see S. Farrell; *An Internet Attribute Certificate Profile for Authorization*, Aug. 20, 1998) that binds attributes such as roles **122**, group memberships and security clearance to a name. However, attribute certificates contain no public key, and that the name specified in the AC is meant to provide supplemental information related to an individual U named in an existing X.509 CertCA(U). Since the name of the certificate holder is included in the AC, then the name and role are linked directly. For the purposes of the method **2**, both certificates **76** and ACs are acceptable because the method uses a certificate containing a role **122** to authorize an action, however, in the method, it is desirable that the role not be associated directly to the user it is assigned to.

[**0048**] Therefore, the method **2** uses an anonymous role certificate **76** (CertCA(U,R)) for user U, which is an X.509v3 certificate with the following changes: (1) the name field represents a fictitious user; (2) there is an extension field containing the role **122** for U ; (3) there is an extension field that contains a forward reference from Cert(U) to Cert(U, R).

[**0049**] The forward reference for example may take the form of E(C, U, passwd) that denotes the public key encryption of the concatenation of U and a password by the company C's public key or the local CA's public key. The forward reference is simply a mechanism for the company to be able to identify the owner of a role certificate, and it has no other importance to the method of the invention. If U has several roles **122** then there will be a role certificate **76** for each role. It is important to note that each role certificate has a public and corresponding private key so that users may produce signatures in their role capacities. Thus each user will have at least two certificates, a standard X.509v3 certificate CertCA(U) that binds their name to a public key, and then an anonymous role certificate **76** (CertCA(U,R)) that binds their role to a public key. CertCA(U) is linked to CertCA(U,R) by a forward reference, but given CertCA(U, R) there is no obvious way to determine CertCA(U) or the identity of U. For the purposes of the method **2**, a signature **106** produced by a private key **124** associated with a role certificate **76** CertCA(U,R) is defined as a role signature **126**.

[**0050**] Thus, if a user produced a signature **126** on a transaction **40**, then a verifier **130** is interested in the role **122** that the user has in the company, such as whether user is a manager or department head, and how this role relates to the given task, if at all. The identity or name of user is in fact not important, as only the role **122** assumed by user is of concern in verifying if a task has been authorized.

[**0051**] Referring now to **FIG. 5**, in order to accomplish the task of verification, the TAM **2** includes a verification submethod **116** that enables the verification of the created and signed document **114**. In a first step **132**, the role signatures **126**, are checked on the document **114**. In a second step **134**, the transaction type itself is checked to ensure that it is an authorized transaction. In a substep **136** of the second step **134**, the role names **122** are extracted from the role certificates **76**. In a second substep **140** of the second step **134**, the names **122** are hashed. In a third substep **142** of the second step **134**, the computed hash value of the transaction **40** is checked to ensure that it is equal to the value of the transaction **40** received in the AS **94**. In a fourth substep **144** of the second step **134**, the signature **126** of the TA **80** on the transaction **40** is checked to ensure that

it is correct. If so, the transaction **40** has been verified and notice of this fact is sent to the requester **42**.

[**0052**] Thus, verification is simply the process of checking signatures, and that the verifier **130** is not concerned with the details **66** of the transaction **40**. It is assumed that the signatories have checked the details **66** of the transaction **40** and would withhold their signature **106** if these details deviated from company policy in regard to transactions of the given type T. This assumption is again inherent in the form-signature model, where the verifier **130** is typically more concerned with the signatures provided as opposed to details of the signed form.

[**0053**] In the remainder of this detailed description, a travel request transaction is used to illustrate the steps of the TAM **2**.

[**0054**] Referring now to **FIG. 6**, the structure of an IBM travel request document **54** is shown. Traditionally, paper documents have been used for various transactions, in particular for authorizing a travel request. It is the task of a Transaction Authority **80** (<<TA>>) (shown in **FIG. 7**) to convert these paper forms into digital documents **64** (preferably in HTML form, although there are several possible formats). For each form, the TA **80** separates out what may be considered as transaction details **66**, and what may be considered as authorization information **146**. For the travel request document **54**, the transaction details **66** include the requester name, destination, the trip cost, dates out of the office, etc. On the paper form, and the HTML document **64** constructed from it, most of the transaction details **66** are simply placeholders for information to be supplied by the requester **42**.

[**0055**] The authorization details **146** generally consist of a list of roles **122** of persons who are required to jointly authorize the transaction **40**. <<Authorizing>> the paper form usually means to sign it, and for the HTML document **64**, the authorization details **66** will indicate which persons acting in which roles **122** may authorize the transaction **40**. For the travel request document **54**, the authorization details **66** that correspond to a permission set **100** for authorizing a travel request, consists of the electronic signatures **106** of the requester **165**, a manager **167** and a departmental manager **169** (shown in **FIG. 9**) This means that the requester **42**, a person acting in the role **122** of manager, and a person acting in the role **122** of departmental manager must digitally sign the HTML form **64** for it to be considered authorized.

[**0056**] Referring now to **FIG. 7**, for the travel request document **64**, the TA **80** creates the travel transaction details **66** in HTML, signs these details and stores the signed document in the Digital Document Database **70**. Thus it is necessary to assign the role of the TA **80** to a person who is issued a TA role certificate **76** (shown in **FIG. 8**) that contains an associated signature verification key **120**. The TA **80** will also be issued separately with the matching signing key **150**. Signatures produced with the TA **80** signing key **150** are verified with the verification key **120** in the TA role certificate **76** (shown in **FIG. 10**).

[**0057**] The TA **80** creates the Authorization Structure **94** for the travel request document **64**, signs the document, and then stores it in the Authorization Structure Database **96**. The Authorization Structure **94** is a representation of the roles that may be used to authorize the transaction **40**.

[**0058**] The information in the Digital Document Database **70** and the Authorization Structure Database **96** are not required to be secret as such. However, it is necessary that the information be integrity protected. For this reason, the TA **80** must sign such documents.

[**0059**] Referring now to **FIG. 8**, details regarding how the Authorization Structure **98** (<<AS>>) is created depend on social and strategic management factors that are not the subject of the invention. The main property of the AS **98** is that its construction depends on the concept of a permission set **100**. To illustrate what is meant by a permission set **100**, let the set PT,**1**={U, M, DH} be the permission set for transaction T. In this example, the transaction T has only one permission set, but in general a transaction may have several permission sets denoted PT,**1**, PT,**2**, . . . , PT,i. Each permission set **100** consists of a set of roles **122** (that is, PT,i⊂R, potentially a multi-set), with the meaning that any user U is authorized for transaction T represented by D(T,U), if for some permission set PT,i={R**1**, R**2**, . . . , Rm} of T, m users in the roles R**1**, R**2**, . . . , Rm sign D(T,U) using their respective role certificates.

[**0060**] Permission sets **100**, (PT,i), then represent sets of roles **122** whose joint authority is deemed sufficient to authorize transactions **40** of type T. A tree **154** (shown in **FIG. 9**) is used to represent the permission sets **100** PT={PT, **1**, PT, **2**, . . . , PT, k}, of a transaction T. With respect to the form-signature model, PT describes the decision procedure for authorizing transactions of type T. U.S. Pat. No. 4,309, 569 to Merkle, the content of which is incorporated by reference, describes the general use of such trees **154**.

[**0061**] Referring now to **FIG. 9**, for each transaction type T, an authorization tree **154**, AT, is created such that there are k nodes **156** at a first level **160** from the root **162**, corresponding to the k permission sets **100**, PT={PT, **1**, PT, **2**, . . . , PT, i}, for transaction type T. The nodes at a second level **164** are leaves **166**, and represent the roles **122** of each permission set **100**.

[**0062**] If the permission sets **100**, PT, for T are PT,**1**={R**1**, R**2**}, PT,**2**={R**3**, R**4**, R**5**} and PT,**3**={R**6**}, then AT **154** has two levels where the first level **160** represents PT,**1**, PT,**2** and PT,**3** with 3 nodes **156** and each PT,i **100** has the same number of leaves **166** as there are roles **122** in its permission set. So for example then PT,**1100** would have two children (both leaves **166**) representing R**1** and R**2**, as shown in **FIG. 10**.

[**0063**] Since transaction **40** is considered authorized if, for at least one permission set **100**, PT,i, signatures are acquired for each role **122** in PT,i, the nodes **156** representing the PT,i may be considered as "AND" nodes **170** and the root **162** of AT **154** as an "OR" node **172**. An AND node **170** means that all children of the node must agree to the request D(T,U) (all roles **122** of a permission set **100** must sign) while an OR node **172** means at least one child must agree to the request D(T,U) (at least one permission set must jointly sign). Alternatively, AT **80** may be interpreted as a disjunctive representation of the roles **122** that can authorize a transaction **40**.

[**0064**] Referring again to **FIG. 8**, with the travel request document **64**, the permission set **100** consists of the requester **42**, a manager and a departmental manager. These will be described in more detail later.

[0065] Referring now to **FIG. 10**, since the AS **98** is based on permission sets **100**, and these sets consist of named roles **122**, each user will be issued with one or more roles designated by a role name. Since users are required to sign in their capacity under a given role name **122**, users are then issued with role certificates **76**. A role certificate **76** consists of the role name **122**, a signature verification key **120**, a Role Manager signature **106** on the role certificate **76**, and other administrative information (such as time at which the role certificate was issued, when it will expire etc.). When a user is given a role certificate **76**, there is also given the corresponding signing key **150** that matches the verification key **120** in the role certificate. In fact, a user demonstrates that he owns a given role certificate **76** by possessing the corresponding signing key **150**. Consequently the signing key **150** must be kept secret by the user it is issued to. Each signed role certificate **76** is also stored in the role certificate database **82** (<<RCD>>).

[0066] The above completes the initialization of the method **2** of the invention. In summary, the initialization involved the conversion of paper forms into digital documents **64**, and their signing by the Transaction Authority **80**. Further, the TA **80** also determined the Authorization Structure **98** (AS) for each transaction **40**, and has signed this AS as well. The information in the AS **98** is based on named roles and the Role Authority **180** issues each user with one or more role certificates **76**. The set of named roles **122** issued by the Role Authority **180** were used by the TA **80** in the construction of the AS **98**.

[0067] Referring now to **FIG. 11**, an example of authorizing a travel request **64** is considered. Assume a user wishes to make a travel request and have it authorized. The user, the requester **42** of the travel authorization, will accomplish this through the help of the TAM **2**. In the preferred embodiment, the TAM **2** is a server application on the company intranet **25**, and can be contacted via a Web interface such as a browser. The user thus is able to contact the TAM **2** via its URL and indicates that he/she wishes to make a travel request **64**. Here, the travel request requester **42** is acting in the role **122** of <<regular employee>>.

[0068] In a first step **182**, the user/employee **42** requests a travel request transaction **40** from the TAM **2**. The TAM **2** receives the travel request **52** from the user **42**, and contacts the Digital Document Database **70** to obtain a copy of the transaction details **66** for this class of transaction **40**. The Digital Document Database **70** returns the details **66**, represented in HTML, to the TAM **2**. The HTML was previously signed by the Transaction Authority (TA) **80**.

[0069] In the second step **184**, the TAM **2** requests the HTML representation **64** of the transaction details **66** from the Digital Document Database **70**. To check that the HTML details are correct, the TAM **2** requests the role certificate **76** of the TA **80** from the Role Certificate Database **82** (which also includes role certificates of a <<regular employee>> **165**, a <<manager>> **67**, <<department manager>> **169** and other roles of employees and management at differing levels within the company), and then verifies the signature **106**. If the signature **106** is correct, the TAM **2** proceeds.

[0070] In a third step **186** the Digital Document Database **70** returns the HTML representation **64** of the travel request transaction details **66**.

[0071] In a fourth step **190**, the TAM **2** requests the role certificate **76** of the TA **80** from the Role Certificate Database **82**. In a fifth step **192**, the Role Certificate Database **82** returns the certificate **76** of the TA **80** and the TAM **2** verifies the signature **106** of the TA on the HTML representation **64** of the transaction request details **66**, returned from the Digital Document Database **70**.

[0072] In step six **194**, the TAM **2** returns the HTML transaction details **66** to the requester **42**, and the requester's browser displays the details as a HTML form **64** that is requesting input. The requested input constitutes the transaction details **66** for the travel request **54**. In step seven **196**, the requester **42** views the HTML representation **64**, completes the details **66** specified (e.g., name, destination, costs, etc.) through the browser, signs the completed HTML representation **64**. The user/requester **42** has signed with their role certificate **76** that indicates the role <<regular employee>>. The requester **42** returns this signed HTML representation **64** to the TAM **2** to collect any remaining signatures **106**.

[0073] In an eighth step **200**, the TAM **2** receives the signed requester input (i.e., the signed HTML representation) from the user **42**, and then contacts the Authorization Structure Database **96** to obtain the authorization structure **98** for the travel request transaction **40**. The TAM **2** receives the authorization structure **98** from the database **96** and checks the signature **106** of the TA **80** on the structure. From the authorization structure **98**, the TAM **2** extracts a permission set **100** of role names **122**, and a collection of users to contact to sign in these role names. In this case there is only one, which is the regular employee/requester **42**, manager and departmental manager.

[0074] At this point, the object of the TAM **2** is to obtain a collection of signatures **106** from persons whose joint roles **122** constitute a permission set **100**. The requester **42** has already provided the signature **106** for the role <<regular employee>>, and the TAM **2** must obtain two signatures in the roles <<manager>> **167** and <<departmental manager>>.

[0075] The TAM **2** accesses a User Directory Database **202** that lists users and their roles **122** and, for example, selects user <<John Brown>>; in role <<manager>> for one signature **106**, and user <<Sue Smith>> in role <<departmental manager>> for the other signature.

[0076] In step nine, the TAM **2** forwards the transaction request details **66** with the signature **106** of the regular-employee requester **42** to a manager of the requester, John Brown. John Brown's browser displays the HTML travel form **64** with the requester's transaction details **66** filled in, and an indication that the signature **106** provided by the requester **42** is correct. John Brown then decides whether to authorize the travel request **54**. If authorization is granted, John Brown signs the HTML of the travel request **54**, and the travel details **66** provided by the requester **42**, which are returned to the TAM **2**.

[0077] In step ten, the TAM **2** forwards the transaction request document **64** with the signatures **106** to the <<department manager>> Sue Smith, who is presented with the details **66** of the travel request **54** and the set of previous signatures on the request (in this case the signature by the requester **42** and that of John Brown). If all is in order, Sue Smith then signs all the information she received in her role as department manager, and sends this back to the TAM **2**.

[0078] In step eleven, the TAM **2** receives a set of signatures **106** that purport to constitute a permission set **100**. To check that this is in fact the case, the TAM **2** retrieves the role certificates **76** for the requester **42**, John Brown as Manager and Sue Smith as Departmental Manager, and then verifies all the signatures. In step twelve, if the signatures **106** verify as being valid, the TAM **2** forwards the document **64** including the signatures and role certificates **76** to the requester **42**. Thus, a digital document **114**, shown in **FIG. 12**, is created including all the authorization details **66** required in order to confirm the validity of the transaction **40**. The requester **42** now holds a set of signatures **106** on a travel request that constitute a permission set **100** for this class of transaction **40**. This information is to be used in convincing another user, denoted as a verifier **130**, that the requester **42** is in fact authorized to make the travel request **54**.

[0079] Referring now to **FIG. 12**, the completed transaction **40** is depicted, having transaction details **66** and the signatures **106** held by the requester **42**, including (1) the HTML of the transaction details signed by the TA **80**, (2) the user-supplied input, both of which are signed by the requester **42**, and (3) this information being over-signed by the a manager, and all being over-signed by a departmental manager.

[0080] Referring now to **FIG. 13**, the role certificates **76** and authorization structure **98** held by the requester **42** are shown.

[0081] Referring now to **FIG. 14**, the steps involving requester **42** forwarding the travel request **54** to the verifier **130**, for transaction processing, is discussed. This method is called a verification submethod **116**.

[0082] To better understand this method of verification, it is important to understand details of how the Authorization Structure **98** is constructed. The verification submethod **116** makes use of cryptographic hash functions, which map arbitrary strings to fixed length outputs of say 16 or 20 bytes. In the case of the travel request **54**, the Authorization Structure **98** is constructed by hashing the three roles **122** (thus hashing the actual authorization structure of the company) that constitute the permission set to yield: H1=hash(<<regular employee>>); H2=hash(<<manager>>); and H3=hash(<<departmental manager>>).

[0083] For example, Hi is said to be the hash of the string (<regular employee>>. Finally, H1, H2, and H3 are treated as strings, concatenated and then hashed as T=hash(H1, H2, H3). The phrase is "the Transaction Authority **80** (TA) signs the Authorization Structure **98**", means that the TA signs the value of T" the transaction **40**. Thus the TA **80** is signing a "hash of hashes".

[0084] All users are aware of this general method for signing an Authorization Structure **98** (AS), in that they know that the AS signed by the TA **80** is derived from first hashing a collection of roles **122**, and then hashing these values once more.

[0085] Referring specifically to the travel request example, the requester **42** sends (1) the travel request **54** in HTML signed by the TA **80**; (2) three role certificates **76** corresponding to three users in roles <<regular employee>>, <<manager>> and <<departmental manager>>; (3) the transaction details **66** as shown in **FIG. 12** which are first signed by the regular employee, then the manager, then the departmental manager; and (4) the signature **106** on the hashed roles **122** as created in **FIG. 15**.

[0086] Referring again to **FIG. 5**, the TAM **2** includes a verification submethod **116** that enables the verifier **130** to verify the created and signed document **114**. The verifier **130** is primarily interested in verifying that the requester **42** is authorized to make the transaction **40**, which in this case is a travel request **54**. The requester **42** sends to the verifier **130** the transaction HTML (signed by the TA **80**), a collection of role certificates **76**, the transaction details **66** signed by each of the signing keys **150** corresponding to the verification keys **120** in the role certificates, and the Authorization Structure **98**. Recall from **FIG. 8** that each role certificate **122** is signed by the Role Authority **180** (RA). In a first step **132**, the verifier **130** uses the verification key **120** of the RA **180** to check each certificate **76** on the document **114**. In a second step **134**, the verifier **130** then checks the signatures **106** on the transaction details **66** using the verification keys **120** in the supplied role certificates **76**. In a substep **136** of the second step **134**, to check that the requester **42** is authorized, the verifier **130** extracts the named roles **122** from the role certificates **76** In a second substep **140** of the second step **134**, the names are hashed using the hash-of-hashes process (as described above). In a third substep **142** of the second step **134**, the computed hash value of transaction **40** is checked against that was originally signed by the Transaction Authority **80** to ensure that it is equal to the value for transaction **40** received in the AS **98**. The output of the hash-of-hashes process is then used as input to check the signature **106** on the hash-of-hashes process. In a fourth substep **144** of the second step **134**, if the produced hash-of-hashes string matches the hashed string signed by the TA **80**, then the verifier **130**, assumes that the request **52** is authorized. If so, the transaction **40** has been verified and notice of this fact is sent to the requester **42**.

[0087] In the above submethod **116**, the TAM **2** transfers the information from the requester **42** to the verifier **130**. Optionally, the transfer from the requester **42** to the verifier **130** may be done via e-mail. The requester **42** gathers all the authorization details **66** locally using the TAM **2** and then sends all this information via e-mail to the verifier **130**. For instance, all the signatures **106** and costs are gathered and then the request **52** is e-mailed to a travel agent who proceeds to make the booking.

[0088] As of yet, it has not been assumed that the requester **42** and the verifier **130** are in the same company. This is not necessary because the method **2** functions regardless of whether the verifier **130** is in the same company or not. If they are in the same company, they may be connected by the intranet **25** and thus share the same server **54***a*. The location of the verifier **130** is not important as such. The role **122** of the verifier **130** is to verify the information provided by the requester **42**.

[0089] In order to verify the validity of the transaction **40**, the verifier **130** needs the following:

[0090] (1) the signature verification key **120** of the Role Authority **180** that is used to check the correctness of the signatures **106** on the role certificates **76** used in the transaction **40**;

[0091] (2) the signature verification key **120** of the Transaction Authority **80** to check the correctness of the

signature **106** on the Authorization Structure **98** (the hash-of-hashes process); and

[**0092**] (3) knowledge of how to take a collection of named roles **122** and perform the hash-of-hashes process so that the signature of the Transaction Authority **80** on the Authorization Structure **98** can be checked.

[**0093**] The signature verification keys **120** of the Role Authority **180** and Transaction Authority **80** are public information, in that they need not be made secret. Therefore, they are assumed to be available and thus verifiable by all. The hash-of-hashes process needs to be understood by all potential verifiers **130** using the method **2** of the invention.

[**0094**] The hash-of-hashes process is quite simple in the example of the travel request **54** given above, because there is only one permission set **100**. However, the basic method **2** can be extended as follows to include several permission sets **100**. For example, a travel request **54** can also be authorized by the CEO and the CEO secretary, so that the two permission sets (P1 and P2) for a travel request are P1={regular employee, manager, departmental manager}; P2={CEO, CEO secretary}.

[**0095**] The permission sets **100** and the roles **122** they consist of can be arranged into an Authorization Tree **154** (AT), as shown in **FIG. 9**. The AT **154** is an example of an Authorization Structure. For the Transaction Authority **80** to sign the AT **98**, the AT must first be converted into a string, which is done by using a hash-of-hashes process similar to that described above.

[**0096**] First, each role name **122** is hashed to give H1,

[**0097**] H2, H3, H4, H5 as follows:

[**0098**] H1=hash(<<regular employee>>)

[**0099**] H2=hash(<<manager>>);

[**0100**] H3=hash(<<departmental manager>>);

[**0101**] H4=hash(<<CEO>>);

[**0102**] H5=hash(<<CEO secretary>>).

[**0103**] These values must now be hashed in order to obtain one hash for each permission set, as follows: H6=hash(H1, H2, H3); and H7=hash(H4, H5). H6 is the hash for permission set P1, and H7 is the hash (P2') on permission set P2. Thus there is one hash for each permission set **100**; these are called permission set hashes. Note that hash(H1, H2, H3) means that H1, H2, and H3 are strings that are concatenated and then hashed. Finally, the hash for the tree is produced as T=hash(H6, H7).

[**0104**] This hashing process is represented in **FIG. 15**. It is the value of transaction **40** that is signed by the Transaction Authority **80**.

[**0105**] The verifier **130** uses a signature on transaction **40** to check that a requester **42** is authorized for a given transaction **40** (travel request **54** in this case) in a similar manner as in the example given above with one permission set **100**.

[**0106**] To verity the signature **106** on transaction **40**, the verifier **130** repeats all or part of the tree hashing process described with respect to **FIGS. 9 and 15**. Note that in **FIG. 15**, hashed referenced items are differentiated from those of **FIG. 9** by means of a prime following the unhashed referenced number. Assume that the requester **42** has obtained signatures **106** from persons acting in roles that constitute permission set PI. In this case, the requester **42** will be sending the verifier **130** three role certificates **76** from which the verifier can extract the roles names <<regular employee>>, <<manager>>, and <<departmental manager>>. The verifier **130** can then form H1, H2, H3 and H6 as described above. Thus the verifier **130** can form the permission set hash of the permission set **100** that authorized the transaction **40**.

[**0107**] To complete the signature verification on the Authorization Tree **154**, the requester **42** will need to provide the verifier **130** with the permission set hashes of all other permission sets **100** besides the one that is authorizing the transaction **40**. In the example above, because P1 is authorizing the transaction **40**, then the hash of P2 must be provided, which in this case is equal to H7 as described above.

[**0108**] When given H7, the verifier **130** can now form T because the verifier can form H6, and the signature **106** on T can be checked. Thus, for the purposes of checking the signature **106** on the Authorization Tree **154**, the requester **42** sends the verifier **130** role certificates **76** from which roles **122** can be extracted and hashed to form the hash of the permission set **100** that is authorizing the transaction; and the hash of each permission set that is not authorizing the transaction. With these two pieces of information, the verifier **130** can compute the hash value of transaction **40** and then check the signature **106**.

[**0109**] In the travel request above, the TAM **2** is contacted through the World Wide Web, and thus the TAM can be thought of as a web server process. In the workflow system of the method, users preferably contact the TAM through a dedicated network channel. Both embodiments are essentially identical: the TAM **2** exists somewhere on the computer system **20** which can be accessed by users; the TAM can also access databases **70**, **82**, **46** and **202**,and other users. As understood in the prior art, this may be accomplished by e-mail or via an intranet or Internet connection to the web, for example.

[**0110**] The TA **80** is trusted by the requester **42** and verifier **130** in that the signatures **106** produced by the TA are trusted. In this sense, the TA **80** is trusted to correctly form the HTML representation **64** of the transaction **40** and sign it, and to also form the Authorization Structure **98** for a transaction and sign it. However, in a broader sense, the TAM **2** need not be trusted. Although a user may trust the TAM **2** to perform some security functions on their behalf, the user may instead use a local process to verify that all the work performed by the TAM is correct.

[**0111**] In the web embodiment, the TAM **2** is neutral (i.e., trusted by all) in that it is an independent server **54***b* accessible by both verifiers **130** and requesters **42** on the Internet **31**. Specifically, the components in which trust really resides is with the Transaction Authority **80** (to create digital transactions, to create Authorization structures), and the Role Authority **180** (to allocate role certificates **76** to persons who can act in the stated role). Thus, the verifier **130** need only trust the signatures **106** produced by the Transaction Authority **80** on the HTML representation **64** and Authorization Structure **98**, and the Role Authority **180** for signatures on the role certificates **76**.

[0112] In the travel request **54** described above, the TAM **2** is performing a trusted role on behalf of the requester **42** since the TAM is fetching information and checking signatures **106**. However it should be clear that all information sits in public databases (the Digital Document Database **70**, the Authorization Structure Database **96** and the Role Certificate Database **82**) resident on the server **54***b*, for example. The requester **42** could access the Digital Document Database **70** and get the travel request HTML document **64** directly, and check the signature **106** of the TA **80** on it (the verification key **120** of the TA **80** is available to everyone). The requester **42** could then contact users for signatures **106** to form a permission set **100**, check the signatures by accessing the Role Certificate Database **82** and so on.

[0113] It should be clear that when the TAM **2** performs the database fetching and signature collection, this, besides being how the method works in practice, is simply a convenience for the requester **42**. If convenience and not trust is the overriding consideration to a user, then the TAM **2** need not be trusted by all parties.

[0114] As mentioned above, the main distinction between intra-enterprise and inter-enterprise authorization is that, in the former case, the company is less concerned about revealing its authorization structures **98** to the verifier **130**. In the inter-enterprise context, the authorization structure is the authorization tree **154** for a given task, and thus access to the database containing the collection of all authorization trees, should be restricted to users outside the company.

[0115] There are several ways to adapt the method **2** as already described to an inter-enterprise scenario. Returning to our original example of a transaction **40** between companies A and B, represented by users UA and UB respectively, the most direct approach would be for each company to have an enterprise authority EA, with a public key that can be used to verify signatures **106** produced by the EA on behalf of the company. The EA authorizes all inter-enterprise transactions by being the verifier **130** of all transactions originating in the company; if a transaction is authorized, then the EA signs a statement to this effect which can be verified by a user in another company.

[0116] Further, although the TAM **2** preferably operates within the distributed workflow management system **6**, the method may simply consist of a message exchange mechanism. In this embodiment, the message exchange mechanism that does not operate as a traditional workflow management system **6**, but instead, manages electronic message flow such as e-mail with attachments or HTML e-mail between the requester **42** and persons having certain roles within the company. The management of such a mechanism being realized through something as simple as PC-resident role-based programs (i.e., programs customized to suit the particular role of the user **8**) using file-server type databases (analogous to databases **70**, **96**, **82** and **202** shown in **FIG. 11**) and pull down menus and submenus organized so as to follow the relational structure of the databases. A typical menu item is, for example "transaction type", which opens a submenu listing different types of transactions (such as "travel request"). Activating a particular transaction **40** can open another submenu showing the permission sets **100** required for such transaction. Activating a permission set **100** then opens up an e-mail having transaction details **66** in an attachment. The e-mail is pre-addressed to all those persons in the permission set **100**, making further distribution for signature and verification simple.

[0117] The embodiment using the hash of the authorization tree **154** described in **FIG. 15** has the advantage that the verifier **130** learns only a small amount of information about the decision structures of the user's company, except that a user in role UR can request a transaction **40**. On the other hand, the EA server becomes a potential bottleneck, as every inter-enterprise request must go to EA for verification and signature. An alternate solution is to make the authorization trees **154** available outside the company on the public Internet **31** for the purposes of verification by other companies. The main problem of course is that by revealing an AT **154** directly, much information about the decision process within a company is revealed. In the next section, several modifications to the method **2** that makes it more suitable for inter-enterprise authorization.

[0118] For example, instead of having to obtain direct approval of every transaction **40** from an enterprise authority (i.e., Transaction Administrator **80** for confirmation that the lower level employees had authority to authorize the transaction, the enterprise authority need only approve of an authorization structure **98**. Now, verification of authorization need not always go to through the enterprise authority-rather, the authorizations need only fulfill the requirements of the authorization structure **98**.

[0119] In another advantage, once the TA **80** has created transactions **40** and authorization structures **98**, and the RA **180** has created role certificates **76**, the system **20** becomes very reliable in that contracts created using the method **2** can easily and automatically be verified.

[0120] It should be understood that the method **2** functions with one-role permission sets **100**. However, an advantage of further reliability in the authorization result is obtained where more than one role **122** is specified in a permission set **100**. Further, a lower resource-intensive embodiment of the method **2** may be obtained by providing for the extraction and verification of a single, say, the first listed role certificate **76** in a permission set **100** comprised of several roles **122**. Defining the structure of a permission set **100** such that the role certificate **76** of the higher-level employee is listed first, improves the reliability of this embodiment. Nevertheless, such an embodiment is inherently less reliable as compared to an embodiment that extracts and verifies all of the role certificates **76**, as well as the role content of the permission set **100** itself (i.e., that the role certificates **76** on a transaction **40** do indeed correspond to the specific roles **122** required to authorize the transaction).

[0121] Multiple variations and modifications are possible in the embodiments of the invention described here. Although certain illustrative embodiments of the invention have been shown and described here, a wide range of modifications, changes, and substitutions is contemplated in the foregoing disclosure. In some instances, some features of the present invention may be employed without a corresponding use of the other features. Accordingly, it is appropriate that the foregoing description be construed broadly and understood as being given by way of illustration and example only, the spirit and scope of the invention being limited only by the appended claims.

Having thus described the invention, what is claimed is:

1. A computerized method having a process flow operating over a computer network comprising a plurality of interconnected computers and a plurality of resources, each computer including a processor, memory and input/output devices, each resource operatively coupled to at least one of the computers and executing at least one of the activities in the process flow, the method comprising the steps of:

assembling an electronic authorization of a transaction;

extracting verifiable role certificates from said electronic authorization; and

verifying whether role certificates, associated with the authorization, are themselves authentic.

2. The method of claim 1 wherein roles associated with the role certificates are hashed and compared with hashed roles in a database of hashed roles.

3. The method of claim 1 wherein the authorization is further insured by verifying that role certificates associated with the authorization correspond with roles in a permission set of roles of an authorization structure, the role certificates of which being required to authorize the transaction.

4. The method of claim 3 wherein the authorization structure is an authorization tree.

5. The method of claim 3 wherein the roles are extracted from the role certificates associated with the transaction, each extracted role being hashed and these hashed roles being concatenated and hashed again, and then concatenated with hashes of other permission sets, if any, according to the authorization structure and hashed once again, resulting in a computed hash value which may be compared to that which was signed by the Transaction Administrator, a match indicating that the transaction is authorized.

6. A distributed workflow management system, the management system operating over a computer network comprising a plurality of interconnected computers and a plurality of resources, each computer including a processor, memory and input/output devices, each resource operatively coupled to at least one of the computers and executing at least one of the activities in a process flow, the system comprising:

code for assembling an electronic authorization of a transaction;

code for extracting verifiable role certificates from said electronic authorization; and

code for verifying whether role certificates, associated with the authorization, are themselves authentic

7. The system of claim 6 wherein roles associated with the role certificates are hashed and compared with hashed roles in a database of hashed roles.

8. The system of claim 6 wherein the authorization is further insured by verifying that role certificates associated with the authorization correspond with roles in a permission set of roles of an authorization structure, the role certificates of which being required to authorize the transaction.

9. The system of claim 8 wherein the authorization structure is an authorization tree.

10. The system of claim 8 wherein the roles are extracted from the role certificates associated with the transaction, each extracted role being hashed and these hashed roles being concatenated and hashed again, and then concatenated with hashes of other permission sets, if any, according to the authorization structure and hashed once again, resulting in a computed hash value which may be compared to that which was signed by the Transaction Administrator, a match indicating that the transaction is authorized.

11. A computerized method having a process flow operating over a computer network comprising a plurality of interconnected computers and a plurality of resources, each computer including a processor, memory and input/output devices, each resource operatively coupled to at least one of the computers and executing at least one of the activities in the process flow, the method comprising the steps of:

assembling an electronic authorization of a transaction;

extracting verifiable role certificates from said electronic authorization; and

verifying whether role certificates, associated with the authorization, are themselves authentic.

12. The method of claim 11 wherein roles associated with the role certificates are hashed and compared with hashed roles on a database of hashed roles.

13. The method of claim 11 wherein the authorization is further insured by verifying that role certificates associated with the authorization correspond with roles in a permission set of roles of an authorization structure, the role certificates of which being required to authorize the transaction.

14. The method of claim 13 wherein the authorization structure is an authorization tree.

15. The method of claim 13 wherein the roles are extracted from the role certificates associated with the transaction, each extracted role being hashed and these hashed roles being concatenated and hashed again, and then concatenated with hashes of other permission sets, if any, according to the authorization structure and hashed once again, resulting in a computed hash value which may be compared to that which was signed by the Transaction Administrator, a match indicating that the transaction is authorized.

16. A distributed workflow management system, the management system operating over a computer network comprising a plurality of interconnected computers and a plurality of resources, each computer including a processor, memory and input/output devices, each resource operatively coupled to at least one of the computers and executing at least one of the activities in a process flow, the system comprising:

code for assembling an electronic authorization of a transaction;

code for extracting verifiable role certificates from said electronic authorization; and

code for verifying whether role certificates, associated with the authorization, are themselves authentic.

17. The system of claim 16 wherein roles associated with the role certificates are hashed and compared with hashed roles in a database of hashed roles.

18. The system of claim 16 wherein the authorization is further insured by verifying that role certificates associated with the authorization correspond with roles in a permission set of roles of an authorization structure, the role certificates of which being required to authorize the transaction.

19. The system of claim 18 wherein the authorization structure is an authorization tree.

20. The system of claim 18, wherein the roles are extracted from the role certificates associated with the transaction, each extracted role being hashed and these hashed roles being concatenated and hashed again, and then concatenated with hashes of other permission sets, if any, according to the authorization structure and hashed once again, resulting in a computed hash value which may be compared to that which was signed by the Transaction Administrator, a match indicating that the transaction is authorized.

21. A Transaction Authorization Method encoded on a computer readable medium, the method having the following steps:

(a) receiving a request for a transaction;

(b) obtaining an electronic representation of a document having details of the transaction from a Digital Document Database;

(c) obtaining the role certificate signed with a signature by a Transaction Administrator from a Role Certificate Database and verifying the signature;

(d) returning the transaction details to the requester;

(e) awaiting and receiving from the requester the completed representation, signed by the requester;

(f) requesting the Authorization Structure for the transaction from the Authorization Structure Database, the Authorization Structure being pre-signed with a signature by the Transaction Administrator and verifying the signature, and choosing a permission set of role names and user members of the permission set to contact to sign in these role names;

(g) forwarding details of the transaction request with the signature of the requester to others having roles corresponding to the chosen permission set and collecting signatures of each role indicated in-the permission set;

(h) requesting role certificates from the Role Certificate Database and signatures for each member of the permission set and encoding the same on the document; and

(i) forwarding the completed electronic document including the signatures and role certificates to the requester, the document including authorization details required in order to confirm the validity of the transaction.

22. The method of claim 21 wherein the role certificates and the Authorization Structure consist of hashed information about permission sets and roles, such hashed information substituting for the unhashed role certificates and permission sets.

23. A Transaction Verification Method encoded on a computer readable medium, the method having the following steps:

(a) receiving an electronic document representing a transaction, associated transaction details being signed by a Transaction Authority, a collection of role certificates certifying named roles signed by a Role Authority, the transaction details signed by each of the signing keys corresponding to the verification keys in the role certificates, and the Authorization Structure;

(b) using a verification key of the Role Authority to check each certificate on the document;

(c) in the following manner, checking the signatures on the transaction details using the verification keys in the supplied role certificates:

i. extracting the named roles from the role certificates;

ii. hashing the roles using a hash-of-hashes process;

iii. checking the computed hash value of the transaction against that was originally signed by the Transaction Authority to ensure that it is equal to the value for the transaction received in the Authorization Structure;

iv. using the output of the hash-of-hashes process as input to check the signature on the hash-of-hashes process; if the produced hash-of-hashes string matches the hashed string signed by the Transaction Authority, then assuming that the request is authorized; and

(d) reporting the result.

24. A distributed workflow management system encoded with a Transaction Authorization Method, the method having the following steps:

(a) receiving means for receiving a request for a transaction;

(b) retrieving means for obtaining an electronic representation of a document having details of the transaction from a Digital Document Database;

(c) retrieving means for obtaining the role certificate signed with a signature by a Transaction Administrator from a Role Certificate Database and verifying the signature;

(d) transmission means for returning the transaction details to the requester;

(e) receiving means for receiving from the requester the completed representation, signed by the requester;

(f) querying means for requesting the Authorization Structure for the transaction from the Authorization Structure Database, the Authorization Structure being pre-signed with a signature by the Transaction Administrator;

(g) verifying means for verifying the signature;

(h) selection means for choosing a permission set of role names and user members of the permission set to contact to sign in these role names;

(i) transmission means for forwarding details of the transaction request with the signature of the requester to others having roles corresponding to the chosen permission set and collecting signatures of each role indicated in the permission set;

(j) retrieving means for requesting role certificates from the Role Certificate Database and signatures for each member of the permission set;

(k) encoding means for encoding the signatures gathered in step (j) on the document; and

(l) transmission means for forwarding the completed electronic document including the signatures and role certificates to the requester, the document including authorization details required in order to confirm the validity of the transaction.

25. The system of claim 24 wherein the role certificates and the Authorization Structure consist of hashed information about permission sets and roles, such hashed information substituting for the unhashed role certificates and permission sets.

26. A distributed workflow management system encoded with a Transaction Verification Method, the method having the following steps:

(a) receiving an electronic document representing a transaction, associated transaction details being signed by a Transaction Authority, a collection of role certificates certifying named roles signed by a Role Authority, the transaction details signed by each of the signing keys corresponding to the verification keys in the role certificates, and the Authorization Structure;

(b) using a verification key of the Role Authority to check each certificate on the document;

(c) in the following manner, checking the signatures on the transaction details using the verification keys in the supplied role certificates:

i. extracting the named roles from the role certificates;

ii. hashing the roles using a hash-of-hashes process;

iii. checking the computed hash value of the transaction against that was originally signed by the Transaction Authority to ensure that it is equal to the value for the transaction received in the Authorization Structure;

iv. using the output of the hash-of-hashes process as input to check the signature on the hash-of-hashes process; if the produced hash-of-hashes string matches the hashed string signed by the Transaction Authority, then assuming that the request is authorized; and

(d) reporting the result.

27. A message exchange mechanism operating over a computer network comprising a plurality of interconnected computers and a plurality of resources, each computer including a processor, memory and input/output devices, each resource operatively coupled to at least one of the computers and being able to read and write messages to be sent to another resource over the computer network, the mechanism performing the steps of:

assembling an electronic authorization of a transaction;

extracting verifiable role certificates from said electronic authorization; and

verifying whether role certificates, associated with the authorization, are themselves authentic.

28. The mechanism of claim 27 wherein roles associated with the role certificates are hashed and compared with hashed roles in a database of hashed roles.

29. The mechanism of claim 27 wherein the authorization is further insured by verifying that role certificates associated with the authorization correspond with roles in a permission set of roles of an authorization structure, the role certificates of which being required to authorize the transaction.

30. The mechanism of claim 29 wherein the authorization structure is an authorization tree.

31. The mechanism of claim 29 wherein the roles are extracted from the role certificates associated with the transaction, each extracted role being hashed and these hashed roles being concatenated and hashed again, and then concatenated with hashes of other permission sets, if any, according to the authorization structure and hashed once again, resulting in a computed hash value which may be compared to that which was signed by the Transaction Administrator, a match indicating that the transaction is authorized.

32. A message exchange mechanism operating over a computer network comprising a plurality of interconnected computers and a plurality of resources, each computer including a processor, memory and input/output devices, each resource operatively coupled to at least one of the computers and executing at least one of the activities in a process flow, the system comprising:

code for extracting role certificates of at least one type from a message; and

code for verifying if said role certificates, associated with the authorization, are themselves authentic.

33. The mechanism of claim 32 wherein roles associated with the role certificates are hashed and compared with hashed roles in a database of hashed roles.

34. The mechanism of claim 32 wherein the authorization is further insured by verifying that role certificates associated with the authorization correspond with roles in a permission set of roles of an authorization structure, the role certificates of which being required to authorize the transaction.

35. The mechanism of claim 34 wherein the authorization structure is an authorization tree.

36. The mechanism of claim 34, wherein the roles are extracted from the role certificates associated with the transaction, each extracted role being hashed and these hashed roles being concatenated and hashed again, and then concatenated with hashes of other permission sets, if any, according to the authorization structure and hashed once again, resulting in a computed hash value which may be compared to that which was signed by the Transaction Administrator, a match indicating that the transaction is authorized.

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